# THE ARMOUR ENGINEER

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**Our Contributors**

THE ARMOUR ENGINEER extends its thanks to those members of the Alumni body who have contributed to this issue. Without exception, the articles show most careful and painstaking preparation, and the matter presented is of an exceptionally high class. That this magazine should have been able to collect these with so little effort signifies a highly gratifying spirit of loyalty to Armour Institute of Technology; especially so, when it is considered that any of the contributions would have received, undoubtedly, a hearty welcome at the hands of any of the standard engineering journals.

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**The Importance of English to the Engineer**

Many engineers, especially those just entering the profession, are inclined to underestimate the value of a knowledge of their native tongue. As an illustration of this attitude, a skeptical student of engineering once asked a teacher of English literature: "How will the study of Shakespeare help me to run a steam engine?" Now it is quite probable that one who does not expect to get any farther than "running a steam engine" will not be

greatly aided in such a performance by studying Shakespeare. But the man who becomes an engineer in the broad sense of the word will need all the command of language which a study of grammar, rhetoric, and literature can possibly give.

An engineer must, first of all, be able to think clearly and accurately. The process is aided by having symbols of ideas. This is quite generally recognized in subjects requiring mathematical treatment, where very abbreviated symbols are used. But it is frequently overlooked that words are the most common symbols of ideas, and an exact knowledge of their meanings is, therefore, a most useful aid in accurate thinking.

An engineer must also be able to express ideas clearly and accurately, as may be necessary in giving instructions to others or in preparing a report upon some subject. In doing this, he must not only use words in their proper sense, but he must arrange them in sentences, and sentences in paragraphs, according to the commonly accepted grammatical and rhetorical order. A study of these subjects is, therefore, of fundamental importance. But supplementing these, there is nothing that can take the place of good examples in illustrating definitions and applications of rules, and it is here that the study of the masterpieces of literature has one of its greatest uses.

The vocabulary of the engineer is as extensive as that of other professions. He may not talk or write as much as the lawyer, the minister, or the author, but when he does, his need of words and a knowledge of how to put them together is as great as that of one in a more voluble profession.

E. H. Freeman.

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**The Engineer in Business**

The idea of public regulation of private corporations has received considerable impetus within recent years due to certain notable disclosures of corporate mismanagement. This, coupled with the recent industrial depression, has awakened the public to an appreciation of its possibilities in the field of corporate control; and hence we see today a firm tightening of the reins, usually manifesting itself by giving unlimited control to various commissions whose duty it shall

be to obtain best service from an operating company, and yet be fair to the company's interests. The tendency is a conservative and rational outcome from the municipal ownership idea, a typical final scene of which is being enacted in Cleveland today.

These commissions are as various in their methods of procedure as in their effectiveness. From the conservative and judicial stand of the Massachusetts and New York State Commissions, it is but a step to the annihilatory and slap-stick decisions and methods of, say, the Oklahoma and Texas Railroad Commissions. In addition to state commissions, we find on the one hand Congress considering problems of conservation of power resources, forest preservation, national water power policy, internal waterways, etc.; and on the other, the city governments are undertaking a solution of broad gauge engineering problems of transportation, lighting, and industrial development, all in the nature of public control of private utilities, or of public ownership and private operation. The Boston Transit Commission, The Public Service Commission First Dist. New York (superseding the old Rapid Transit Commission, and others), and The Chicago Board of Supervising Engineers, are typical of city commissions, which, though varying greatly in power, are fast becoming the pivot for civic utility corporation control.

Taking it all in all, the Public Utility Commission, or its equivalent, has come to stay; and we are fortunate in presenting elsewhere a most excellent analysis by Mr. H. C. Abell of certain problems that are encountered in the conduct of business of these commissions. There is today a pressing need of a solution, or at least a uniform working basis, for each of the very practical questions considered by Mr. Abell; and on their being found or not, largely depends the working efficiency of these commissions, an efficiency measured by the criterion of "a square deal for all."

Although the administrative and routine work of the commissions require the keenest analytical judgment, and an intricate working knowledge of utility corporation operating problems, it is significant that but a small percentage of the

members are chosen from the engineering profession. Thus, in the two New York Commissions we find of ten men, but one an engineer. To be sure the commissions retain many prominent engineers in a consulting capacity, but there is strong reason to believe that their working efficiency would be greatly expedited if the commissions were constituted of at least as many engineers or former operating managers, as of lawyers and business men.

The very qualities that enable an engineer to solve a purely scientific problem with accuracy and dispatch, are remarkably effective when applied to an administrative problem of corporate operation or management. To illustrate this point, we cite an actual instance occurring during the conduct of business of a certain noteworthy public utility engineering commission. A running comparison was desired between various operating constants (energy per car mile, length average passenger trip, schedule speed, etc.), for each month from the beginning of an extensive rehabilitation program up to the present time. These were desired for comparison with similar items obtained in another city. The Auditing Department advised that the figures were not available, and an engineer was sent in to dig out the information. In a very short time, the results were plotted in graphical form on curve sheets, and incidentally many desirable operating improvements were made manifest. When these curves were brought to the attention of the Auditing Department and business men of the commission, the reply was that it might be true but that the curves did not mean anything to them. That is to say, the ability to quickly grasp an operating problem; or rather, to realize the problem and its necessity for solution, was with the engineer, and not with the auditor, or lawyer.

What may therefore be called the new engineering, is the application of the principles which formerly the engineer employed in specialized research, to those bigger problems, heretofore considered the special province of the lawyer, banker, or business man. By so doing, the engineer immediately takes his position on the social scale commensurate with his extensive preparation and peculiar ability. An incidental, though

very gratifying outcome from this development, is that it can no longer be said, as was the case ten years ago: "I can hire the best engineer in the country for $3,000 per year."

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**New Ideas of Chemical Engineering**

During the last few years many new ideas have been put into execution on the education of Chemical Engineers. We believe that Armour Institute of Technology is among the leaders of this new movement, and that its graduates are being fitted to take responsible positions in industrial plants immediately after graduation.

A few years ago, the graduates in chemistry from most schools were Chemists instead of Chemical Engineers. They had to spend from two to three years after graduation in industrial work before they were well enough acquainted with actual practice to be efficient in first class positions.

Today the practice here is to give men the actual work in the laboratory, a complete plant for the manufacture of which comes up in operating plants. For instance there is, sugar from the sugar beet. Thus the actual operation of diffusion, carbonatation, filtering, bleaching, and boiling down the juices in vacuo are carried out. The crystals are built up in the vacuum pan, and the strike centrifuged in the ordinary way. The beets used are dried and ground by a special process, so that the plant may be operated any time during the year. The difficulties which may be encountered in ordinary practice are studied closely, and considerable data obtained on the best methods for sugar houses.

There is also a complete set of apparatus for the destructive distillation of wood and peat. Methyl alcohol, charcoal, and the other by-products are obtained, and the best methods of analysis of still liquors, etc., are studied. This is practice rarely obtained in ordinary chemical courses.

Tests are being run on the foundry cupola. Complete heat equations are obtained for ordinary cupola practice, and from them, theoretical charges are calculated and run. The success met with has well paid for the labor of the tests, and further researches are being carried on. This is very new work and is of great advantage to the students.

Besides the actual industries studied, industrial researches such as the fixation of nitrogen from the air, the utilization of garbage and sewage, electro-chemical industries and many others are being carried on. Apparatus is provided for almost any such research that the student may wish to carry out.

The students here have also the advantage of the great industries of Chicago. The largest and best plants of each industry are visited during the year. Besides watching the actual operation the men have to collect data from practice and write a detailed description of each plant. This gives them much valuable information which could not be obtained in the laboratory. The result of this training is that our graduates are ready to take responsible positions at once, and not only carry out the work necessary, but have such a complete knowledge of the best practice, that they are ready with suggestions to overcome the deficiencies and losses so common in all industrial plants.

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**Technical Education**

There is no doubt that the organization of courses in modern American technical schools has been developed with a thoroughness which admits of but slight improvement, and that the engineering colleges of today are remarkably efficient, all things considered.

A difficulty most apparent to all close observers of technical student life is that caused by lack of personal system and method on the part of the student, by virtue of which much time is spent on unproductive study, energies though well intentioned, are misdirected and the net result of a long period at school is small compared with what might have been the case had the student attained an early clear idea of his own relations to his school and profession; a knowledge of what to remember and what to leave; an early adaptation to the technical magazine, card index, and loose leaf habits; a tendency to cultivate acquaintance with engineers; to take summer jobs on engineering work rather than in some unrelated activity. In a word, to be " on the firing line " instead of considering himself as one apart from his profession until

graduation. Too often do we hear the statement from a student that he is just beginning as a Senior to clearly understand his Junior work, etc.; that he is just beginning to "get the drift" on things which should be old stories. Also we continually hear from the Alumnus how differently he would do it if he could be a student once more. The fault is not with courses but with the inability of the student to quickly find himself.

After these considerations are clearly brought home to the student, and he has attained a certain facility in practicing them, it is remarkable how rapid his progress becomes. A long period of apparent mediocrity, which may even extend years after graduation, is suddenly changed to one of quickly increasing abilities and attainments. It is at this rising bend of the curve that the Alumnus tells how he would do it again at school, or if the student is so fortunate as to attain this point while at school, he remarks to what better advantage his time might have been put while a Sophomore or Freshman. Very often we experience the case of a mediocre student making the best ultimate success, due entirely to latent possibilities rendered unavailable while at school from a mistaken idea as to the necessity for their exercise.

On this account we desire to question the policy of technical schools of weeding out members of Freshman and Sophomore classes on a scholarship basis. Too often do we see the live young man, usually with money and an hereditary tendency to good living and physical well being, expelled from school because he cannot or will not learn Calculus or Physics. These men ultimately find themselves in other lines of endeavor and reach the highest plane of success. It is undeniable that many excellent men have been lost to the engineering profession on this account, and in their place we have the residue who were good students during the weeding out period; but many of whom as men and potential engineers are not to be compared with the good fellows who leave college when Sophomores or Freshmen.

This is to our mind the most glaring fault of the present system of technical education. It is an outcome of a tendency

for instructors to make much of the bright student, and to depress the poor one; largely to gratify his own craving for quick response to his teaching. The poor student becomes aware that he is not wanted, or feels that he can never master "this truck," and voluntarily leaves, or is requested to do so on account of poor marks. This requires urgent remedy, since in a great number of cases the facts are that the so-called poor student is potentially the best man in his class. An unselfish, well balanced, broad minded teacher with an accurate knowledge of the value of his own course to the completed whole, will do much to correct the condition stated; but it seems to be the case in technical schools that the experienced instructors are reserved for upper classmen, and new instructors of untried, or second-class, ability are allowed to determine the makeup of future Junior and Senior classes.

It is only necessary to glance impartially at the personnel of the Junior and Senior classes at various engineering schools to realize that many mistakes have been made. That is to say, a delay of the waking-up process in a man beyond his Sophomore year is made into a handicap affecting his entire future; and in many cases reacting on the profession of engineering detrimentally, by shunting good men into other lines of activity. That such a condition should be allowed to exist is unfair to the student, to the upper class professors, and to the profession of engineering.

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**Proposed Improvement in the Sugar Industry**

It has come to our notice that an exceedingly important change in a great industry is being developed by the aid of research carried on in the laboratories of the Armour Institute of Technology. The industry affected is the sugar industry, and the change consists in a probable decrease in the cost of manufacture. The work is not yet in complete form and will probably appear in detail in a later issue. We consider, however, that it will be one of the greatest industrial reforms ever effected by such an institution as this. The essential changes consist in drying the sugar-bearing material and thus giving refineries a chance to

work the entire year; also in saving valuable by-products which now go to waste. The result is a considerable saving in the cost of producing sugar.

It is an interesting to note that the by-product from sugar is a fine paper stock, easily convertible into the best quality of magazine paper. With the present stir about the conservation of our natural resources, such a saving would confer a great benefit, not only upon the sugar industry, but also on the country in helping to have our forests. It has been estimated that one Sunday edition of the Chicago Tribune uses the paper made from ten acres of spruce. If the newspapers and magazines can be printed on paper from an annual plant like sugar cane, instead of wood pulp, it would mean a saving to us of thousands of acres of forest each year.

This problem has been with us a long time without being solved; and if Armour Institute of Technology proves the means of helping us to a quick solution, which seems very probable, we believe that a very large and long feather has been added to a cap, already well plumed.

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**Forced Ventilation and Interpoles**

Whenever a new device is introduced having for its purpose one specific object, it is often found that the combination of this with other unrelated devices will make possible still more remarkable results. Such is the case with the combination of forced ventilation and interpoles in the direct current series railway motor.

The interpole, originally designed to aid commutation and thus reduce maintenance charges, has succeeded so well as to have practically eliminated commutation as an output limitation on the motor. Those remaining are limitations of mechanical strength and allowable temperature rise. Certain tests conducted by the Public Service Corporation of New Jersey, and others, some years ago have shown it possible to decrease by one-half the temperature rise of a standard non-interpole motor, by the expedient of forced ventilation. Up to the present time the converse of this proposition—namely: doubling the output from a motor of given frame size by forced

ventilation has not been possible. The reason for this is twofold. During the accelerating period, at which time the motor current has high value, the output cannot be increased since commutator sparking is prohibitive. Again, the output for continuous operation cannot be doubled, since the design of a motor with a speed curve permitting efficient operation at this doubled output is difficult. The reason for this is also to be ultimately found in commutation limits of design.

Hence before the advent of the interpole, forced ventilation was only effective in reducing temperature of windings, without permitting the motors to be operated at such an increase of momentary or continuous output, that the number of motors per car could be decreased, or a sufficiently smaller frame size be used to allow much saving in first cost of equipment. For this reason, the proposition of forced ventilation never has appealed to the railway manager.

At the present time, however, it is entirely possible to construct a motor with interpoles and forced ventilation that will have nearly double the specific output of a standard non-interpole motor. This assumes equal temperature rise in each case. This statement has been borne out by actual tests on such a motor; and there is every reason to believe it to be a future standard method of operation, for the larger size motors at least. For instance it is entirely possible to take, say, a standard 75 horse power 600 volt railway motor, provide it with interpoles; and rewind, so that its speed curve will closely approximate that of a 150 horse power motor. If, now, this motor be equipped with forced draft appliances, it will duplicate in every respect the performance of a 150 horse power motor of present standard design, both as regards continuous and momentary outputs. That is, we can substitute for a four motor equipment of 75 horse power motors, which is a typical interurban equipment, two of these forced ventilated motors; and the car performance will be identical in every respect, provided slipping point of the wheels is not reached by this doubling of concentration of power per axle.

The economics of the problem stand in tabulated form somewhat as follows, for this particular case:

### First Cost of Electrical Equipment per Car

| | |
|---|---|
| Four motor equipment— | |
| 4 75 H. P. motors and control | $4,400 |
| Two motor equipment— | |
| 2 Interpole motors wound with 150 H. P. characteristics, and control | $2,600 |
| Forced ventilating blower and ducts | 200 |
| Total | $2,800 |

### Annual Charges per Car.

| | |
|---|---|
| Four motor equipment— | |
| 12% Interest, depreciation, and taxes on $4,400 | $ 528 |
| Power for traction, 30 ton car, 55,000 car miles per year, 100 watt hrs. per ton mile, 2 cents per K. W. hr. | 3,300 |
| Total | $3,828 |
| Two motor equipment— | |
| 12% on $2,800 | $ 336 |
| Power for traction, same basis except 26½ ton car (saving on motors of 7,400 lbs. plus ventilating set, 400 lbs.) | 2,920 |
| Power for Ventilating set, 1.5 K. W. for 2,800 hrs. | 84 |
| Total | $3,330 |

That is, a saving of $500 per car per annum. This does not include that due to possible saving in cost of trucks, or in lower maintenance cost per car.

# DIFFICULT PROBLEMS WHICH PUBLIC UTILITY COMMISSIONS ARE ENDEAVORING TO SOLVE.

By H. C. ABELL.*

**First**: The Total Value of a Property; which includes the physical or tangible value, as well as the so-called intangible value.

**Second**: The Proper Rate of Return on that Valuation, so that capitalists can be induced to invest in a more or less hazardous business instead of real estate, mortgages, etc.

**Third**: The equitable method of charging the users of the commodity and establishing standards—whether it be for a cubic foot of gas, a kilowatt of electricity, a gallon of water, a telephone call, or a car ride, so that each user pays to the Public Utility for service rendered an amount which shall bear a proper relation to the cost which he occasions the utility.

**Fourth**: Some method of increasing the rate of return to the Public Utility on its valuation in some proportion to the decreased cost to the public, as an incentive to the Utility to develop its business and decrease its cost per unit, and thereby decrease its selling cost to the public.

It appears at first glance that these problems should not be difficult of solution, but an analysis soon develops the perplexing and trying difficulties.

## FIRST PROBLEM

**Total Valuations**; which may be divided into physical and so-called intangible valuations.

**Physical Valuation**: Engineers can estimate, at prevailing prices, what it costs to replace a certain piece of apparatus, or a collection of pieces concentrated on one portion of ground or under one roof, which may be called the plant or power house, but they cannot, with the same accuracy, estimate

(a) What has been the average price paid since the utility first commenced serving the public, including the increased cost of new apparatus installed when just developed, over the later prices after the apparatus becomes standard and patents have expired;

(b) What will be and what has been the cost of necessary changes, due to the ill fitting together of these parts;

(c) What will be the changes in the art during construction, necessitating changes in plans and construction;

(d) What the increased cost will be, due to climatic or labor conditions;

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(e) The kind of soil and quantity of water to be encountered in all excavations;

(f) The cost of accidents, employers' liability, public liability, fire, wind, water, etc., breakage of machinery, temporary work, such as coffer dams being washed out during construction, and various other items;

(g) The increased cost of construction during operation, due to idle labor waiting for an opportunity to work, and to temporary work installed (in order to avoid interruptions to service) which is removed after permanent work is finished;

(h) The increased operating expenses, which are unavoidable due to construction work going on;

(i) The length of time necessary to construct a plant, which would affect interest while building, taxes during construction, engineering, etc.;

(j) The cost of obtaining all the actual necessary money to build the plant, and to put it on a self-sustaining basis;

(k) The unforseen litigation, injunctions, etc., which frequently increase enormously the original estimated cost;

(l) The cost of the corporate organization of the company;

(m) What the actual cost will be over the estimated cost—due to increased cost of material and labor since estimates were made, and to ommissions, etc.;

(n) The necessity of laying out works, purchasing property, erecting buildings, etc., in order to provide for future extensions—at a minimum cost for the future;

(o) The present value of the plant, after depreciating the various items to allow for obsolescence, inadequacy and decay, and the enhanced value, which will be considered under intangible valuation.

**Intangible Valuation:** It is also impossible for engineers to estimate, with accuracy the intangible valuation, which involves a consideration of

(a) The expense of obtaining a proper and efficient operating organization;

(b) The expense of maintaining an operating organization to develop business and to popularize the utility and the use of its product during the construction period, so that the plant can commence operating with the greatest possible revenue;

(c) The cost of advertising—including newspapers, posters, periodicals, personal solicitation and practical demonstrations of various kinds;

(d)The cost of appliances which are given away, or loss on their sale which includes free installation;

(e) The loss due to operation until the utility is on a paying basis;

(f) The loss in interest and profits on the investment, from the first operating period to a time when expenses and interest are earned:

(g) The enhanced value of the utility due to the increased value of its real estate, location of plant, accessibility of water, railroad facilities and sewerage, location of pipes, conduits, etc. in the streets—the latter costing much less for installation, special fittings, moving of manholes, etc., when no obstructions are met, to the extent that these items are not given full consideration in making the physical valuation;

(h) The enhanced or decreased value—due to the utility while operating having assisted and participated in the loss or development of the town or city. The utility having been an active participator in the development of the city, must be entitled to at least the same recognition as any active merchant or banker, whose business, as a going concern, is worth something; and the utility is entitled to even more consideration, since it cannot pick up its pipes, conduits, and plant and move to another city. The inactive land owner is much better off than the utility in that although he takes the same chances in the development of the city, he takes no other chances and assumes no responsibility; whereas, the utility has actively assisted in all developments, taking the many chances of loss to which only a utility is heir, including the risks involved in the work of construction, development, and financiering;

(i) The loss in the change of apparatus, due to obsolescence or inadequacy, which could not be charged as an operating expense and still maintain rates which would hold the customers and permit the financing of the company for necessary changes and extensions. One of the many examples was the changing of monocyclic generators which had been installed but a short time. An example, with which the writer is familiar, is the difference between the purchase price and the price obtained after abandonment (a change having been essential), which amounted to a depreciation of forty per cent per annum. The utility company could not possibly maintain its rates and finance this change due to evolution and development, any more than could a manufacturing concern (which had experienced the same rapid change in the art, as had many utility companies), if it were not permitted to add a charge for the cost of experiment and development to the sale price of its commodity. In the case of the utility, it is the development of the art for more efficient and reliable service in competition with other sources of supplying heat, light, etc.;

(j) The expenditures in replacing the appliances free of cost to the consumers, due to a change in the art. An example would be: a change of motors from DC. to AC. system, from one cycle to another, and that of operating voltage, necessitating the change of all lamps and appliances. All utility companies have experienced this expense, though it does not show in a replacement inventory.

The Tentative Method, now used by one of the Commissions to arrive at reproduction and present physical values, is as follows:

**Reproduction Value**: Five year averages are obtained from the various units which go to make up a whole; then the freight, estimated cost of installation and handling are added. To the sum of these items, which are supposed to make a completed whole, is added a percentage for engineering, interest while building, and incidentals. To the above two items is added the stock, (coal, appliances, etc. on hand), and to this, the cost of paving, making a grand total for replacement. The following is a summary:

| | Reproduction | Present |
|---|---|---|
| 1. Land | — | — |
| 2. Distribution System | — | — |
| 3. Power Plant Equipment | — | — |
| 4. Buildings | — | — |
| 5. Office Furniture, Appliances | — | — |
| 6. Tools, Implements & Machinery | — | — |
| 7. Horses, Wagons & Miscellaneous | — | — |
| 8. Total Items 1 to 7 | — | — |
| 8. Add —% for Engineering Supervision, Interest during Construction and Contingencies | — | — |
| Total 1 to 8 | — | — |
| 9. Stores and Supplies | — | — |
| 10. Paving | — | — |
| Total Items 1 to 10 | — | — |

**Present Value**: The present value is arrived at as follows: By consultation, discussion, and investigation, a tentative life of each unit is taken; then the junk value is ascertained from values of old copper, iron, etc.; by deducting the junk value from the reproduction value, the depreciating value of the unit is obtained. The present value, if in first class operating condition, is obtained by taking the age of the unit and deducting

the amount which would have accumulated in a reserve fund had an amount been set aside each year, bearing a certain per cent interest, which would, at the end of its life, have equaled the total depreciating value; its junk value is then added. If in fair operating condition, ten per cent is deducted from the present depreciating value and, if operating, but in poor condition, twenty per cent is deducted from its present depreciating value; to either of the above values would be added the junk value. To illustrate this method of arriving at present value, we may assume that the reserve fund is to be set aside at four per cent compound interest; that the cost of the unit is $1200 new; that the tentative average life is twenty years; and that the junk value is $200, and that we wish to determine the value at the end of ten years; first, when in first-class condition; second, when in fair condition; and third, when operating but in poor condition. Deducting $200 junk value leaves $1000 as the cost of the depreciable portion of the unit new. The amount to be set aside each year at four per cent, compound interest, to equal $1000 at the end of twenty years, would be $33.58. The amount set aside each year for ten years, together with its accumulated interest, would be $403.

Deducting $403 from $1000 leaves $597, to which must be added the junk value, $200, making a present value of the unit, if in good operating condition of $797; if in fair operating condition, ten per cent is deducted from $597, making the total present value $737.30; if operating but in poor condition, twenty per cent is deducted from $597, making the present value $677.60.

Minimum service values are allowed for the various units which from point of age, might make the value of the unit equivalent to junk only, though it would be in useful operation. For instance, electric meters, which are subject to state or municipal inspection, or both, and have to be kept in a certain state of repair at all times, are allowed a minimum service value of 80 per cent of the reproduction cost; whereas, with a steam engine that has been in service a number of years but which may be in a good state of repair though not having the same efficiency as a more modern engine, or sufficiently good to be put in a newly built plant, only 25 per cent of its reproduction value is allowed.

There is a great diversity of opinion among engineers as to the approximate correctness of the above method of arriving at present value.

Some engineers claim that each unit should be gone over, first obtaining its reproduction value, and then depreciating it in proportion to the cost of making the unit practically new.

Other engineers think that in addition to the above, a further amount should be deducted for depreciation in proportion to the change in the art.

Still others think that the present value of a plant should be estimated on a basis relative to most modern apparatus. As an example: Suppose it is the desire to obtain the value of a water power plant of 1000 K.W. capacity, with a load factor of 40 per cent. A figure would first be obtained for the most economical steam plant of this capacity, which, for illustrative purposes, we will asssume to cost $100,000. Further assuming that the cost per K.W. hour is one cent, not including interest, and that the water power plant can develop current at 5-10c per K.W. hour on the same basis as that taken for steam, then the saving per K.W. hour, by using the water power plant, would be 5-10c, or on a 40 per cent load factor (3,504,000 K.W. hours per year), the saving would be $17,530. This sum capitalized at ten per cent (the allowable rate of return on the investment) would make the value of the water power $175,200 more than that of the steam, or give the water power a total value of $275,000. The depreciation is assumed to be included in the operating expenses.

All the above methods are influenced by the personal equation.

## SECOND PROBLEM

**Rate of return on the valuation**: Before taking up the rate of return, I will refer to the depreciation and the amount to be set aside therefor. The line of demarcation between depreciation and maintenance is difficult to follow. Some engineers and managers think that maintenance and depreciation should all be an operating expense, as it is essential to keep a plant up to a certain point of repair at all times. They think when a piece of apparatus is replaced, the difference between the amount received for it, either as junk or an old piece of apparatus, and the cost of the apparatus replacing it, should be charged to plant account. Others think the difference between the actual cost of the old apparatus and the new should be charged to the plant account, and that the cost of the old apparatus should be charged off to an operating maintenance account. They also think that the utility enhances in value as the city develops in a larger proportion than the depreciation occurs.

Others think that an amount should be set aside each year sufficient to cover the depreciation according to assumed lives. For instance, to take the example of $1200 previously mentioned, $50.00 would be set aside each year for twenty years, if the apparatus should last that long.

There are also various opinions as to how the fund should be treated and financed.

The Commission, previously referred to, when obtaining present values, used four per cent compound interest curve, knowing that the apparatus had actually reached its present life. As to the future, however, it is difficult to prognosticate what these lives will be; in fact, we are certain that a portion of the plant will not reach the estimated lives of its several parts, and that a portion may be in useful operation long after it has from point of age reached the junk value. It would seem that an amount should be allowed that would cover the probable depreciation with reference to any specific financing of the fund, and the amount be changed, either reduced or increased, as necessity requires and actual experience teaches.

If an amount be set aside each year to cover the probable depreciation, some properties would soon be in the hands of a receiver, as they would be unable to meet necessary obligations. Commissions will have to use their judgments in this matter.

The rate of return has to be large enough to induce men of money to invest in a more or less hazardous undertaking. The investment is certain to increase continually as the city develops.

The utility is subject to all the various municipal and state laws which may be passed and enforced, but unlike a life insurance company or other concern, it is not able to move away and still collect premiums from the residents of the state or municipality, or take all of its property with it.

Nearly every utility has strong competition, necessitating continuous changes. In fact, the competition with itself, in many instances, is very detrimental to returns on the investment. For instance, more efficient appliances are frequently brought out, using only 40 or 50 per cent of the commodity formerly used with old appliances. As the utility still has its investment, capacity and practically the same consumers' expense, it must devise methods and means for increasing the use to its present consumers, increasing their standard of illumination, etc. It is not probable that this can be done, especially to this large extent. To increase sales with additional consumers can be accomplished only with additional investment. The solution of this problem requires the most serious thought and best management.

It is almost unnecessary to make any mention of the changes which entail very heavy depreciation and enormously increased expenditures, without any increase in earnings such as art, municipal regulations, liability to accident, increased

cost of material from which the product is manufactured, increased cost of labor, the necessity of continuous operation during the light as well as heavy demands, strikes, changes of plant, etc., when all other manufacturing concerns can shut down.

A public utility is a barometer of the condition of business. When factories shut down, the street railway patronage immediately falls off, light and fuel bills are decreased, all of which means a cut from the net profits of the utility, as its fixed expenses are practically the same.

## THIRD PROBLEM

Establishing standards of service which will be fair to both the consumer and the utility, and which will be paid for by the consumer in proper relation to the cost which he occasions, and at the same time allow the utility to compete with the various other forms of light, heat, travel, etc., is a problem of large and wondrous dimensions.

In order to arrive at any solution, it is necessary to consult the manufacturer of apparatus and appliances, the operator of the utility, and the user of the utility's product. The opinions and claimed experiences of persons under each head vary greatly; but still more diversified are those of the manufacturer, operator and user. By a study of the opinions, experiences and rules already in force in various places, it is possible to arrive at some tentative rules, regulations and specifications of quality, pressure, accuracy of measurement, etc. As it is the duty of a Commission to study the various variables which enter into the cost of a product, and endeavor to arrive at a saleable and purchasable mean, they have to ascertain the quality which should be supplied, which necessitates a knowledge of the material from which it is manufactured. For example, the coal available for gas manufacture may have a high percentage of sulphur, and in order to produce a gas which would compare in the amount of sulphur present to another gas from other coal, which might be very high priced but low in sulphur, would so increase the cost of gas that it would be out of proportion for the results accomplished.

The relation between candle power and calorific value varies with the different manufactured gases. For instance, to obtain the same calorific and candle power values with coal gas as is obtained with water gas, might mean an increased cost wholly out of proportion to the results obtained.

An allowable variation of gas pressure of a fixed number of inches of water, whether the pressure is high or low, might work a hardship on either the utility or the customer. By a

study of the appliance and the application of the law of the flow of gas through an orifice it is possible to arrive at a mean which is fair. As an example: a rule not allowing over 1½ inches of water differential pressure on any consumer's premises would be an exceedingly close regulation and commercially impossible for a total city distribution system though it is possible that such a regulation might, if the matter were not thoroughly understood, be inaugurated.

As the flow of gas through an orifice is as the square root of the differential pressure, therefore increasing the pressure from 1½ in. of water to 3 in. of water would increase the flow 40.6 per cent while increasing from 3 in. to 6 in. would increase the flow only 41.6 per cent, or hardly more than from 1½ in. to 3 in. Practically all appliances are built to take care of this variation of 100 per cent, especially the Bunsen or induced air draft mixer. Take the formula

$$\tfrac{1}{2} Mv^2 = \tfrac{1}{2} M'(v')^2$$

v being the velocity of the gas leaving the nozzle of the inductor, $v^1$ being the velocity of the air and gas together after mixture. If $v^I$ remains constant, and v, the nozzle pressure, varies, then with about 40 per cent increase in velocity, theoretically, about 200 per cent more air will be drawn in, so, allowing for mechanical loss in efficiency of apparatus, enough air would be brought in to make the proper combustible mixture. A differential pressure of 1½ in. between initial and final pressure would pass 52,000 cu. ft. of gas through a mile of pipe, with an investment of $15,840, while a 3 in. differential pressure would pass 73,000 cu. ft. of gas, or 40 per cent more, through the same mile of pipe.

From the above it can be seen that a rule specifying a certain differential pressure as 1½ in. would mean a greatly increased investment and not help the consumer much more than the 100 per cent allowable variation in pressure from a minimum which is allowed by one commission.

Even the latter allowance, if strictly followed in every case and for all hours of the day, might work a hardship on the customer and the utility by necessitating the payment of interest on a heavy investment for a very short period of use.

It can be seen that the establishing of standards and forcing the utility to comply with them in every particular, is a problem for engineer, financier and economist.

Equitable charging would have to be based on the cost of the consumer to the utility, in order that each consumer might bear his proper proportion of the expense which he

occasions. As an example: a large store may have a demand of 400-16 candle power lights and only use them on an average of one hour per day; whereas, a small concern may have a demand of only 20-16 candle power lights and use them twenty-four hours per day;each would consume the same amount of current; each consumer's expense would be approximately the same; the output expense for current consumed would be approximately the same; but the capacity of the generating plant equipment, lines, transformers, etc., would be twenty times more for the large store than the required capacity for the smaller concern. It is, therefore, necessary to subdivide the expense in order to ascertain what the expense of an additional consumer will be, what the fixed expense will be per unit of capacity demanded, and the cost of the commodity per unit sold.

There are some expenses which are common only to the consumers, such as reading meters, delivering and collecting bills; others, proportionate only to output, such as coal carbonized for gas manufacturing; and still other expenses proportionate to output and capacity, such as steam. A part of the steam is used to operate exhausters, which take gas from the hydraulic main. The amount of work performed is in proportion to the gas made; whereas, the amount of steam used for heating the buildings and keeping the holder cups from freezing in the winter, is not in any way influenced by the amount of gas manufactured by that capacity of plant. To go into the several items of expense and endeavor to arrive at a correct subdivision would take considerable space. As an illustration, I will touch on one or two items:

The steam account for electric generation is very difficult of analysis between fixed and output expense. If engines were operated continuously at the most economical load, the cost per unit generated would be less than at variable loads, which actually occur in an electric plant. Boilers are frequently banked, and all the fuel used for banking fires or starting up a boiler each day for peak loads is probably a capacity expense. Engine and dynamo labor, and frequently boiler room labor, would be no greater if all the engines were running continuously at 100 per cent load factor. It can be very plainly seen that as the load factor increases, the operating expenses are decreased per unit of electricity sold.

In order to approximate a correct proportion to be charged to capacity, it would be necessary to assume for a basis, some ideal load factor.

There is a great diversity of opinion regarding the division of General Expense which usually includes executive salaries, general office expense, general office clerical salaries, office rent,

legal expense and an incidental general expense, like the publishing of annual reports, stockholders' meetings, etc. Some accountants call this a contributary or overhead expense and divide it in proportion to the sum of manufacturing, distribution and collection expenses which are subdivided into capacity, consumers and output.

The interest on the investment is frequently subdivided in the same proportion between the capacity, consumers and output, as the example of the general expense just given.

A tentative summary of the division of Yearly Expenses for a Gas Plant are given below:

| | Capacity. | Consumer. | Output. |
|---|---|---|---|
| Manufacture .............. | $ 2,288.65 | $......... | $38,839.00 |
| Distribution .............. | 7,531.79 | 12,929.92 | 1,917.00 |
| Collection ................ | 230.66 | 3,775.35 | ......... |
| Operating Expense, except General Expense ...... | $10,051.10 | $16,705.27 | $40,756.00 |
| General Expense .......... | 2,156.74 | 3,594.57 | 3,626.98 |
| Depreciation .............. | 8,405.00 | 1,845.00 | 2,000.00 |
| Rate of Return ........... | 7,460.09 | 12,500.69 | 30,445.22 |
| | $28,072.93 | $34,645.53 | $81,828.20 |

$1.27 per meter, $8.45 per consumer, 78c per M for gas.
22,000 Meter light capacity connected, 6 cu. ft. per light.
4,100 Consumers.
105,000,000 cu. ft. of Gas Annual Sales.

From the foregoing figures the fixed charge for the various connected capacities would be as follows:

| | |
|---|---|
| 5 Light Meter per Year........ | $ 14.80 |
| 10 Light Meter per Year........ | 21.15 |
| 20 Light Meter per Year........ | 33.85 |
| 30 Light Meter per Year........ | 46.55 |
| 45 Light Meter per Year........ | 65.60 |
| 60 Light Meter per Year........ | 84.65 |
| 100 Light Meter per Year........ | 135.45 |

Besides the above fixed expenses the consumers should pay 78c per thousand cubic feet for gas

A complete analysis of the consumers' accounts should now be made, together with their connected capacities for demand; then, by taking the maximum rate per unit for the commodity at that time in force, and applying the following equation:

$$A + Bx = Cx$$

it is possible to see how many of the customers should have their bills raised or lowered.

A=Yearly charge on the connected load or demand.
B=Output cost of gas.
C=Maximum rate per M. cu. ft. then in force.
x=Number of cu. ft. of gas used per year.

Example: Assume a five light meter was installed and that the maximum rate for gas was $1.25 per M. cu. ft. How many cubic feet per year would a consumer have to use in order to pay the company all expense which he occasions it, together with a proper rate of return on the investment, when the capacity expense is $6.35, consumer's expense $8.45, and output price of gas 78c per M. cubic feet?

A—$6.35+$8.45=$14.80
B—78c.
C—$1.25.
$14.80+.78x=$1.25x
x=31,500 cu. ft. per year

By the foregoing method it is found that 80% of the total consumers had not been paying the amount which they should.

The difficulty of obtaining and installing rates which are fair and equitable and at the same time sufficiently satisfactory to the prospective customer who is not now, but after a proper introduction to the use of the commodity, may become a very profitable consumer, is obvious. There are many rates in use and it devolves on a Commission to study them all, together with an analysis of costs, and endeavor to arrive at something which will be the most equitable for all concerned,—a task which is more than arduous.

### FOURTH PROBLEM

To increase the rate of return to the public utility in some proportion to the decreased cost to the public.

There are several methods now used, or proposed, to accomplish the above results, based on the "London Sliding Scale," or some modification of it.

The first part of the problem is to set the initial price, which, of necessity, has to be fair, whether it be a maximum or average price per unit for all the commodity sold. After solving problems two and three, the price will be fairly well determined for an established concern. To obtain this price requires study and investigation, and a thorough knowledge of all the factors for each specific case. The cost of material

from which the product is produced varies, as do practically all the factors which go to make up the cost. The price has to be sufficient to take care of any normal fluctuation, without working detrimentally to either the customer or to the utility. Whenever any abnormal variation in the price of material, etc., occurs, it has to be taken care of by some other means. Sometimes a certain per cent is set aside in a reserve fund until it reaches a certain amount—a percentage of the investment, gross earnings or some such basis. This fund is kept to take care of variations in price of manufacturing material, decreased earnings in bad years, etc.

A solution of Problem No. 2 will give the initial percentage to be allowed as a rate of return on the investment, after which the ratio of increased allowable net earnings to decrease in price, will have to be determined.

As the price is decreased it becomes more and more difficult to make further reductions, hence a Commission has to determine whether these increased premiums to the utility should be on a differential scale to stimulate greater effort on the part of the utility to improve the physical and financial service to the public, or whether some permanent arrangement should be enforced allowing a utility a fixed per cent increased net earnings, with a specific decrease per unit of the commodity sold.

Whatever method of increasing the rate of return is used, it will have to include the consideration of the availability of service, extensions in new districts, etc.

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I have suggested but four general problems. As has been seen, each of these involve many intricate and difficult questions which will undoubtedly require many years of study and labor to properly solve.

# PERSONAL SYSTEM AND THE CONSTRUCTING ENGINEER.

By R. M. HENDERSON.*

Among the net results of a technical education should be found an ability to clearly diagnose the conditions of a given problem, and the further ability to constantly follow a clearly defined plan in completing its solution.

A technical man, therefore, in attacking an actual problem such as building a power plant or a large industrial plant would naturally be expected to give some evidence of his superior training in his methods of conducting the work.

During my experience as a constructing engineer in active charge of such undertakings, I have been impressed by the number of men in positions of responsibility who were working, not only without having a comprehensive grasp of conditions, but also without formulating a complete plan of operations. This is a weakness which at once stamps a man as an inefficient executive, whose results should be carefully watched, for one can hardly expect a man to give a satisfactory solution of a problem whose conditions he is unable to state.

There is nothing mysterious about the trouble which these men seem to have, neither is it necessarily insurmountable. The root of it lies in a failure to apply to every-day work the principles taught in class room and laboratory. Few men indeed make the most of undergraduate lessons, and as a rule it is a considerable time after graduation before the average man gets down to business in an efficient manner.

There are three questions which at first thought must appear quite simple, for many men slide over them without appreciating their real significance; and yet, men to fill positions of responsibility would be even more scarce than they are now if all applicants were truthfully to answer them. They are:

1. When attacking a new problem do you make it a rule to form a comprehensive idea of what you are setting out to do, before beginning work, or do you commence work blindly, like one in a maze who hopes to stumble upon the right way out?

2. Have you any personal system by which you promptly obtain this perspective or bird's-eye view of your problem,

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*Class 1902. Assistant Construction Manager, Stone & Webster Engineering Corporation. Boston, Mass.

and by which you supplement this general view with a closer, more intimate knowledge as rapidly as conditions will permit?

3. Do you carry this system through consistently to the end, so that at all times you have an accurate conception of the governing conditions of your work?

Personal system is a first aid to executive ability; and if you do not consciously or unconsciously follow some such system, you have missed the essence of all technical training and will be condemned to a life in positions of minor responsibility.

This may seem so self-evident as to render extended discussion unwarranted, but it is noteworthy that in many factories, engineer's, contractor's and business offices will be found methods and forms for enabling and compelling men to be systematic. The methods vary widely in detail but they all have the same common purpose. This is sufficient proof that the average man is deficient in this direction.

Instances of deficiency in personal system are most frequently encountered by the supervising officer who makes occasional unheralded trips of inspection to distant jobs. The Superintendent of Construction who lacks system, may have honestly devoted all his energy to the work but he has not "crammed" for this unexpected examination and he accordingly attempts to magnify his superficial knowledge of the job as a whole, so as to conceal his ignorance of its essential details. Questions as to the condition or cost of some particular part of the work or as to the date on which some other part will be started, or finished, frequently elicit only a call for an assistant, who supplies the information which the superintendent himself should have.

What I have to say, then, hinges on these injunctions: Know your situation; know what you are trying to do; clearly and definitely map out your work so that you know all the simple elements of your problem which, as a whole, may be quite complex.

Make no actual move until you have worked out as complete a plan of operations as the available information will admit, and you understand the inter-dependence of the various steps you must take, and you know what external conditions can affect you and how.

Devise methods of knowing at all times the condition of every sub-division of every part of your work. You should be able, every hour of the day, to give a clear and comprehensive answer to the question: "What is the situation?" for in no other way can you be its master.

Nowhere is the need of this sort of practice more apparent than in the work of a construction engineering company which sets practically no limits on the location or scope of its operations. Power stations in Massachusetts and Florida, an office building in Washington, a hydro-electric development in Montana, electric railway construction in Michigan and Texas, and a gas plant in Louisiana, are among the score or more of varied contracts which may be under way simultaneously. Each has its field organization, which mobilizes almost over night, does its work in a few weeks or months, and scatters again to the four winds—all except a handful. The superintendent and a few men he has found worth carrying, go to the next job, a thousand miles away, to form the nucleus of another small army which may need to be in smooth working order in less than a week.

Through the courtesy and liberal policy of a corporation of this character with which I am associated, I am permitted to describe some of the methods and to reproduce some of the forms which have a direct bearing on the personal system of its field men. The efficiency of its scattered construction organizations has been greatly improved by living up to the requirements of these and other forms which, in a definite manner, provide the superintendent with needed information at the very beginning of a job, as well as all through its progress. He, in turn, is required to supply the Home Office with data of a nature that is difficult to obtain by hit-and-miss methods. He is assisted in doing this by simple forms and charts that are applicable to most of the company's work and is encouraged to develop others to meet any special conditions that will warrant the trouble. Simplicity and the absolutely negligible amount of clerical labor involved in filling out the forms and charts are the secrets of their success.

The opportunity for lost motion increases with the size of the organization and the extent to which it must be departmentized. In the case of this company the Superintendent of Construction is responsible to the Construction Department at the Home Office and will deal through that Department with the Engineering, Purchasing, and Accounting Departments, and will have direct relations with the Executive Department, numerous sub-contractors, and representatives of the client. His own office force will include such clerical and technical assistance as the size of the job dictates, and he will be called upon to do more or less engineering in connection with matters which can best be determined in the field.

He will be constantly under a cross fire of conflicting necessities, for he will be urged to "hurry up and get the job

done in record time " and at the same time will be reminded that " the cost must not exceed the estimate," and he probably had no hand in the making of the estimate.

To attain this paradox—high speed and low cost—on the same job, is not an easy task, and yet it is the usual demand made of the superintendent. In order that he may approximate a satisfactory result in these fundamentals he must be constantly alert to prevent delays of all sorts, due to a thousand causes.

In the very beginning he should take steps to ascertain definitely just what he is expected to do in connection with every detail of the entire job. Following is a list of some of the principal points to be covered:

1. What plans, or specifications, will have to be prepared in his office?

2. What bills of material will be made up for him by the Home Office, and what will be made by him?

3. What purchasing will be handled by the Home Office and what by him?

4. What purchasing assigned to him shall be done directly by his office and what shall be handled by his requisition on the Purchasing Department of the Home Office?

5. What material or apparatus purchased by the Home Office will be erected in place by sub-contractors and what by his own forces?

6. What material, or labor, will be furnished by the Owner?

7. Dates of promised shipment of material, and beginning and completion dates of sub-contracts placed by both the Home Office and his office, should be tabulated so he may guard against delays and interference of the different parts of the work. He should have prompt advice of any changes in these dates and advice of all shipments made.

8. What is the nature of the accounting system and what special cost records, other than the essential accounting records, are required?

Other points to be covered can be added to the list depending on the nature of the work to be done.

He will perhaps have to start work when only a few partially finished plans are ready and in this event will, of course, be unable to secure answers on all these points before beginning work, but this does not prevent his following up the system as rapidly as the engineering of the work will allow.

It is most difficult for a superintendent to obtain this information when he moves from a completed job to a new one without returning to the office. On arriving at the new one

he finds perhaps just enough plans to start excavation or the wrecking of an old building.

If the office attempts merely to write a letter telling him what he is to do and what they are doing, important items are very apt to be overlooked. A trip to the Home Office might require a week or two and would not entirely eliminate this trouble.

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## WORKING SCHEDULE.

The "Working Schedule" meets such conditions, as well as the more normal ones attending the beginning of any new job. It is printed on tracing cloth and is ordinarily filled out on a typewriter, and changes may be made as required. Each week such additions or changes are approved as indicated by the initials of the engineer in charge, the chief engineer, and the officer of the Construction Department in charge, and a revised print is sent to the superintendent.

The Schedule reproduced (Fig. 1) is from a job now in progress, which includes extension and reconstruction work in two power stations in one city, a 13,000 volt transmission line to a new sub-station in a town ten miles away, and the revamping of the distribution system at the latter point. An unusual amount of engineering is left to the superintendent, and a study of this schedule will show the extent and value of the information which can be condensed in one simple form. For instance, in the case of the "Stack Foundation" the superintendent sees that plans and specifications will be furnished him; that only a partial bill of material will be furnished and that he will have to look out for the balance; that he will purchase only part of the material; that he is to build the foundation with his own forces; that the material purchased by the Home Office on order No. A-8 will be shipped on 6-29-08. The next item—"Stack & Flue"—assigns no responsibility to him except following up the sub-contract C-1154, let by the Home Office. His attention is called to the penalty and bonus clause attached to the sub-contractor's date for completion (8-12), and he realizes that he himself must have the stack foundation completed as soon as possible after 6-29, in order that the stack sub-contractor may have no claims for delay or extension of time.

In the case of "Sub-station Wiring" he will have no plans furnished him except the manufacturer's diagrams accompanying the transformers and switchboard panels and he will have to lay out the circuits, order all his material, and install the wiring to the apparatus. Other items show that the apparatus is also to be erected by his men.

Letters written from time to time explain in detail any points which may not be completely covered on the form.

Each week, on an old print of the schedule, the superintendent cancels the "J's" and "S's" corresponding to work he has completed, and sends it to the Home Office where the original is brought up to date from his standpoint.

S & W. E.C. 127A

**STONE & WEBSTER ENGINEERING CORPORATION**
**WORKING SCHEDULE**

KEY
E - ENGINEERING DEPT.
J - CONSTRUCTION DEPT. (LOCAL)
S - SUBCONTRACTOR

WORK FOR Woonsocket Electric Machine & Power Co. JOB NO. 422
WORK COVERED Power Extensions
APPROVED ENGINEERING DEPT. BY W.N.P. DATE 8/28/08.
APPROVED CONSTRUCTION DEPT. BY Keith DATE 8/24/08

| DATES OF REVISION | APPROVALS | ITEM | PLANS | SPECIFICATIONS | BILL OF MAT'L | PURCHASE OF MATERIAL | ERECTED BY | ORDER OR CONTRACT NUMBER | FACTORY SHIPMENT PROMISED | DELIVERY AT JOB PROMISED | ERECTION PROMISED |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 8/25 | [illegible] W.N.P. Keith | 375 Kw. Gen. Foundation | E | | J | J | J | | | | |
| 8/28 | [illegible] W.N.P. Keith | 170 " " " | J | | J | J | J | | | | |
| 9/4 | [illegible] W.N.P. Keith | Stack Foundation | E | E | E/J | E/J | J | A-8 | 6/29/08 | | |
| 9/12 | [illegible] W.N.P. Keith | Stack & Flue | E | E | E | E | S | C-1154 | Penalty & Bonus | | 8/12 |
| 9/18 | [illegible] W.N.P. Keith | Damper Regulator | | | J | J | J | | | | |
| 9/25 | [illegible] W.N.P. Keith | Coal & Ash Machinery | E | E | E/J | E/J | J | (A-148 (A-166 (A-167 | 9/22/08 10/1/08 | | |
| 10/2 | [illegible] W.N.P. Keith | Piping Changes | E/J | E | E/J | E/J | J | | | | |
| 10/9 | [illegible] W.N.P. Keith | Pipe Covering | E | E | E | E | S | (A-216 (A-100 | Upon notification Stock | | |
| 10/16 | [illegible] W.N.P. Keith | Venturi Meter | E | E | E | E | J | A-107 | At once | | |
| 10/23 | [illegible] W.N.P. Keith | 375 Kw. Generator & Exciter | E | E | E | E | J | ) )D-5 | (11/5/08 | | |
| 10/30 | [illegible] W.N.P. Keith | 370 " " " " | E | E | E | E | J | ) | (10/16/08 | | |
| 11/6 | [illegible] W.N.P. Keith | Belting, Pulleys, etc. | E | E | E/J | E/J | J/S | | | | |
| 11/13 | [illegible] W.N.P. Keith | Shafting Changes | E/J | E | E/J | E/J | J | | | | |
| 11/20 | [illegible] W.N.P. Keith | Switchboard | E | E | E | E | J | D-6 | (8/16/08 | | |
| 11/27 | [illegible] W.N.P. Keith | Switchboard & Mach. Wiring | J | | J | J | J | | (10/3/08 | | |
| 12/4 | [illegible] W.N.P. Keith | Tie Line- #1 & #2 Stations | To be installed by Owner. | | | | | Done | | | |
| | | Connections to Tie Line | J | | J | J | J | | | | |
| | | Meters on old Switchboard | J | J | J | E | J | A-215 Requisition on Boston. | At once. | | |
| | | Transformers | E | E | E | E | J | A-103 | 10/9/08 | | |
| | | Woonsocket Sub-Station | J | J | J | J | J | | | | |
| | | Franklin Sub-Station | E | E | E/J | E/J | J | | | | |
| | | Franklin Arc Mot. Gen. Set | E | E | E | E | J | | | | |
| | | Franklin Switchboard | E | E | E | E | J | A-139 | 10/20/08 | | |
| | | Sub-Station Wiring | J | | J | J | J | | | | |
| | | Reconst. Franklin Overhead System | J | | J | J | J | | | | |
| | | Transmission Line | E/J | E | J | J | J | | | | |
| | | " " Copper | | E | J | E | J | A-87 | Req. on Boston | | |
| | | Reconst. Franklin Power Lines | J | | J | J | J | | | | |
| | | New Meters - Franklin System | J | J | J | E | J | Requisition on Boston | | | |

*The Armour Engineer*

FIG. 1. WORKING SCHEDULE.

This weekly exchange of information continues as long as the particular job requires, and has been found to eliminate a large amount of letter writing and lost motion, as well as much uncertainty that formerly existed in the fixing of the responsibility for carrying out the details of the work.

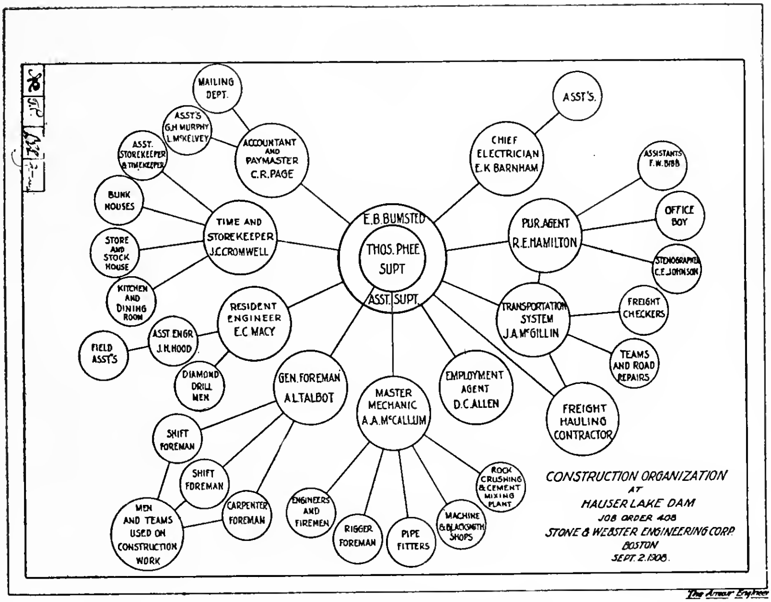


Fig. 2. Organization Chart

## ORGANIZATION CHARTS.

At the beginning of a new job, the size of the field organization usually increases rapidly to a maximum and then decreases gradually as the work approaches completion. Much money may be wasted in pay rolls if men are hired to soon or kept on the rolls too long.

An organization chart or diagram along the lines of the one shown (Fig. 2) is required of the superintendent as soon as he has his forces lined up. Revised charts are required as the progress of the work suggests to the Construction Department the possibility of reducing the organization or the advisability of increasing it. Live superintendents usually anticipate these requests for revised charts, following the beginning or completion of a large item on the job.

In making such a diagram the superintendent is com-

pelled, in a definite way, to justify the existence of all his principal assistants, and the periodical revisions call his attention to possibilities of trimming the payroll which might otherwise be overlooked.

The copy posted in the office stares him in the face every time he goes in, and is of further value as it clearly shows the men to whom they are responsible and so eliminates disputes as to authority.

Also, the Construction Department may be able to detect faulty organization methods or to make helpful suggestions.

The chief value of the chart, however, is the moral effect on the superintendent of putting his line-up on paper, with the consequent clarifying of his own ideas.

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## DELIVERY SCHEDULE.

The importance of closely following the deliveries of material is almost invariably underestimated by the younger superintendents until a few costly delays have brought the matter forcibly to their attention. As an example, the lack of a few special steel pipe fittings on one job tied up all the piping for nearly two weeks, and to meet the operating requirements of the clients it was necessary to secure temporary fittings of cast iron by express to finish a line to a badly needed engine. When the steel fittings finally did come a month later, they had to be substituted for the temporary fittings nights and Sundays at overtime wages.

In addition to the overtime and the duplication of the work, there was a further loss due to the fact that the temporary fittings could not be used elsewhere and had to be sold at a loss. It is true, perhaps, that no system would have prevented all of the delay, but had the superintendent known of it earlier, he might have taken steps to push the shippers or to secure partial shipment by express, which, though costly, would have been cheaper than buying temporary fittings. The actual loss in this case was several hundred dollars.

The delivery schedule (Fig. 3) is sent by the Home Office to the superintendent at least once a month, and during the rush part of the job once a week, and in addition items of special importance may be followed by letter. The schedule is made in triplicate; one copy going to the Construction Department, where a watchful eye is kept on the delivery of material, and two copies going to the superintendent, who returns one copy to the Purchasing Department with any changes he desires noted in the column left for the purpose and headed "Delivery Desired." The Purchasing Department will then apply special pressure to the shippers of these items.

**STONE & WEBSTER ENGINEERING CORPORATION.**

DELIVERY SCHEDULE
OF
BOSTON ORDERS
ON ACCOUNT OF WORK FOR
Tampa Electric Company

JOB ORDER NO. 417
DATE OF SCHEDULE 9/1/08

| ORDER OR CONTRACT NUMBERS | SHIPPER | MATERIAL | DELIVERY DESIRED | FACTORY DELIVERY DATES ORIGINAL | REVISED | PARTIAL SHIPMENTS |
|---|---|---|---|---|---|---|
| A-155 | Abendroth & Root Mfg. Co. | 1 length 24" spiral pipe | | 9/8 | 9/8 | --- |
| A-160 | Ashton Valve Co. | 2 4" safety mufflers | | 9/4 | 9/4 | --- |
| A-150 | H.P. Converse Co. | Reinforcing material | | 8/31 | ------- | --- |
| A-149 | F. A. Houdlette & Son | Pipe and Fittings | | 9/19 | 9/19 | 9/8 |
| A- I52 | Star Brass Mfg. Co. | Angle & globe valves | | 9/5 | 9/7 | --- |
| A-156 | Walworth Mfg. Co. | Pipe fittings | | 9/2 | --- | --- |
| A-128 | Geo.F.Blake Mfg.Co. | 1 20" Relief valve | | 9/5 | Valve 9/8 complete | --- |
| A-134 | Burt Mfg. Co. | 1 12" Ventilator head | | 8/21 | | 8/29 comp. |
| A-I38 | Crane Company | Steel Gate valves | | 9/I5 | --- | --- |
| A-133 | General Electric Co. | 2 Jeweler's Lathes | | 8/20 Stock | 9/2 | --- |
| A-76 | General Elec. Co. | 29 Combination switches | | 8/I7 | 9/5 | --- |
| A-62 | General Elec. Co. | 1 generator panel 1 exciter panel | | 9/10 | 9/24 | --- |
| A- 64 | General Elec. Co. | 1 exciter and bracket | | 10/16 | 10/19 | --- |
| A-58 | General Elec. Co. | Recording Wattmeters. | | 7/28 | 9/24 | --- |
| A-141 | Hohmann & Maurer Mfg. Co. | 4 thermometers 2 mercury wells | | 8/27 As soon as pos- ible | 9/I6 | --- |
| A-I32 | M. W. Kellogg Co. | 12" Header | | 9/5 | 9/9 | --- |

*The Armour Engineer*

FIG. 3. DELIVERY SCHEDULE

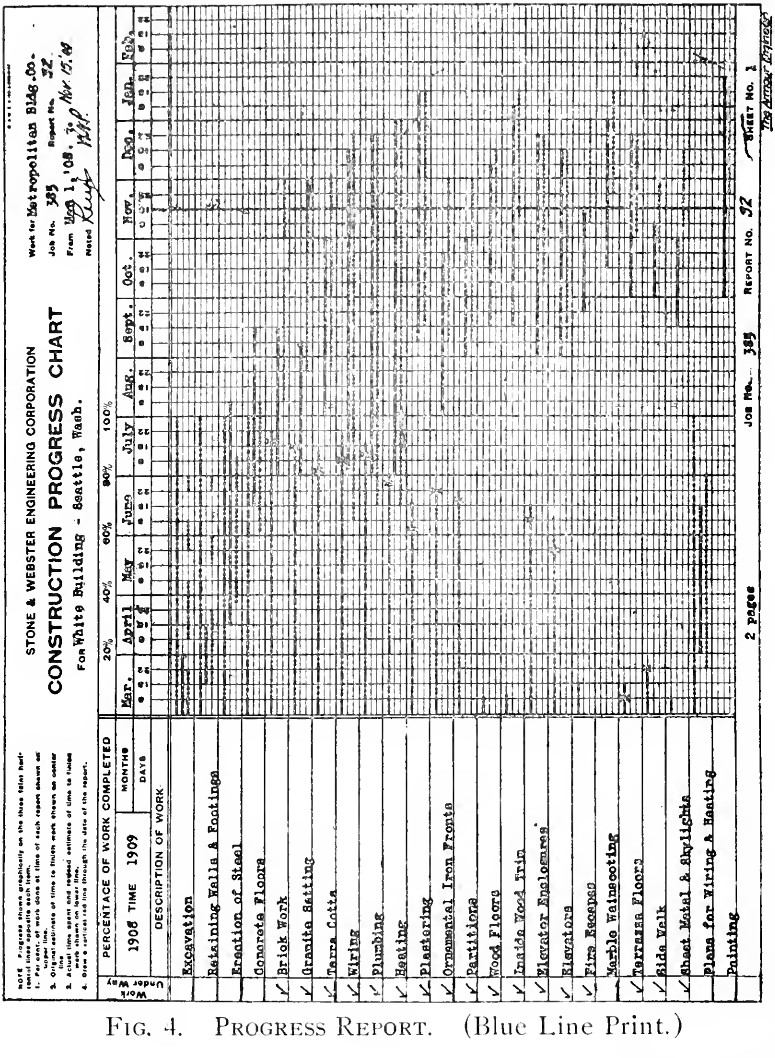


FIG. 4. PROGRESS REPORT. (Blue Line Print.)

NOTE—Progress shown graphically on the three faint horizontal lines opposite each item.

1. Per cent of work done at time of each report shown on upper line in black (on this figure dash dot line.)

2. Original estimate of time to finish work shown on center line in blue line (on this figure solid line.)

3 Actual time spent and revised estimate of time to finish work shown on lower line in red (on this figure dotted line )

4. Vertical red line drawn through date of report.

## PROGRESS REPORTS.

One of the easiest ways of starting a hot argument among construction men is to open up the subject of progress reports. Field men are inclined to chafe and wax eloquently profane at the very mention of them, although inwardly they may recognize their value and necessity. The making of the daily, weekly or monthly report of progress is about the most distasteful of all the superintendent's duties, with the possible exception of the preparation of the financial reports and estimates of cost. Obviously then, that system of progress reports will be the most successful which furnishes the Home Office the required information with the least expenditure of time and effort on the part of the superintendent. Letters are the least satisfactory and the most trouble. Printed forms are better, and for some kinds of work cannot be excelled. But for all around use on any and every kind of work such as is handled by the average general engineering construction firm, some form of graphical report is found to give the best results.

The graphical report form shown (Fig. 4) is quite simple as it covers only the elements of time and work. It has been applied to a wide range of operations, and there is probably no class of work to which it could not be adapted.

Like the working schedule, it is printed on tracing cloth and the Home Office fills out on the tracing the list of items on which progress is to be reported, the "original estimate of time required to finish work," which fixes the chronological sequence of the different items, and the dates and data at the top of the sheets. The Superintendent is then supplied with a stock of blue line prints of the chart on which to render his weekly reports. A number of sheets may be required for a large job.

The "original estimate of time to finish" each item is usually made by a construction official, but if important local conditions are unknown at the Home Office, the Superintendent may be called upon to make the estimate, which in either case answers two purposes:

1. It sets a pace for the men on the job, as material variations from this original estimate must be accounted for, and explanations are not popular.

2. The Superintendent sees at a glance if he is ahead or is falling behind the schedule of time which will bring him out right at the end of the job, and he can trace the cause of the delay and make special efforts to crowd the items which are lagging.

The operation and interpretation of the chart may be easily understood by reading the story of the item "Terra

Cotta.'' The center one of the three horizontal lines opposite this item was ruled in on the tracing by the Construction Department before making the blue line prints on which the Superintendent renders his reports. It shows the performance that the Home Office expects of the Superintendent—i. e., he should be able to erect the Terra Cotta between August 1st and November 1st. The Superintendent rules the upper of the three lines in black, showing that 87% of the work is completed. The little cross indicates the percentage complete at the time of the previous week's report, so the progress for the week just past has been about 5% of the whole.

The Superintendent also rules the lower of the three lines in red ink showing that work actually commenced August 23d; that it has been prosecuted intermittently up to November 15th, the date of this report (as shown by the vertical red line ruled through that date); that he now estimates that the item will be completed December 1st. The total time for completing the Terra Cotta will then be a week less than was originally estimated by the Home Office.

Thus by simply drawing two straight lines, one black and one red, the superintendent has told how much he has done since the last report, how much in all and how long he has been in doing it; how much remains to be done, and how long it will take to do it. There are, of course, a multitude of forms that such a chart may follow, and the element of cost as compared to the estimate can be combined without greatly complicating it.

A very delicate feature is the "original estimate of time to finish" made by the Home Office, which sets a pace for the Superintendent to beat if he can. Obviously this estimate must be a fair one, made by a man who knows construction possibilities and impossibilities. An underestimate takes the heart out of a man who knows he cannot possibly make the dates, and an overestimate lets down the pressure, as the man feels that he can satisfy the office without particular exertion.

## COSTS.

A detailed estimate of the total cost is supplied by the Home Office, but this estimate may have been made before the plans were completed, and in extreme cases may even have been made on a unit basis when only the general outlines of the job were settled.

The wise superintendent, therefore, will divide this detailed estimate into a very much finer series of subdivisions and will check it as closely as possible, as his accumulating

plans and other needed information arrive. By so doing he will frequently be able to show exactly why and where the original estimate is at fault, and by so advising the Home Office will effectively protect himself against later charges of negligence, improper cost keeping, or still worse, of being unable to control his costs.

For a number of generally accepted reasons, the matter of cost keeping has become one of recognized importance on practically all construction work. This is not as simple a matter on a construction job as it is in an office or a factory, for the reason that the entire field organization is more or less temporary and, as a rule, does not reach a point of high efficiency until the work is well under way. Furthermore, the timekeeper, material clerk, and accountant, who are the superintendent's mainstays in the keeping of costs, are all too often deficient in the requisite experience and appreciation of the importance of this part of their work.

It is not at all uncommon to find that the accountant will split a 36c freight bill between four different accounts, the material clerk will haggle over a proper charge for a dozen lag screws, while the timekeeper will distribute the time of the men with a frightful disregard for accuracy, and at the end of the week will juggle $100 into the nearest column to make his classified labor total agree with the total of the payroll.

Another common difficulty arises from the fact that at the beginning of the job the superintendent is apt to think he is too busy getting it organized and under way, to sit down and think much about costs, and when the first month's cost sheets are brought to him, along at the end of the second month when the brick work is half up, he finds a mass of impossible excavation and foundation costs, and proceeds to doctor them up as best he can and apologetically advises the Home Office that those particular figures are not entirely trustworthy. Such costs as these are practically useless and lessen confidence in the rest of his figures, and yet they are the variety that are turned in from many a job as the basis for future estimating data. Such guess work could have been prevented by spending a few minutes a day with the men who are responsible for the cost keeping.

The material costs seldom go far wrong, but the labor costs must be everlastingly watched, and it will pay big returns to insist on having a classified time sheet for each day and to take the necessary few minutes to check and approve it. This may be made a weekly affair after matters are running smoothly and the daily sheets are found to be free from errors. Only a little time is required to check the sheets as

S & W E C 130-6-1000-2-08

**STONE & WEBSTER ENGINEERING CORPORATION**
**UNIT COST RECORD**

JOB ORDER No. 405
ACCOUNT NO 766
SHEET No 1 - only
DATE COMPLETED July '08

COST OF Bonding — 2550 ft. Single Track — Ft. Worth Tex.

| DATE 1908 | AUDIT VOUCHER NO. | DISTRIBUTION | MATERIAL | LABOR | TOTAL |
|---|---|---|---|---|---|
| July | 6 | Payroll | | 25 20 | 25 20 |
| " | 14 | Repairing Grinder | 1 50 | | 1 50 |
| " | 32 | Payroll | | 12 20 | 12 20 |
| " | 34 | " | | 55 00 | 55 00 |
| " | 35 | Express on Bonds and Grinder | 10 20 | | 10 20 |
| " | 37 | Rail Grinder and Accessories | 27 50 | | 27 50 |
| " | 41 | Gasoline | 5 25 | | 5 25 |
| " | 42 | Bonds 148 @ .29½ | 43 77 | | 43 77 |
| " | 48 | Solder | 5 95 | | 5 95 |
| " | 52 | " | 4 95 | | 4 95 |
| " | 55 | Repairs to Grinder | 2 50 | | 2 50 |
| " | 61 | Solder, Acid, etc | 10 72 | | 10 72 |
| " | 63 | Tools | 1 55 | | 1 55 |
| " | 65 | Solder, etc. | 1 54 | | 1 54 |
| " | 66 | Credit - Tools transferred to Job Or #419 | 30 63 | | 30 63 |
| " | 67 | Bonds 40 @ .31 | 12 40 | | 12 40 |
| " | 68 | Credit - Cash Receipt - Dallas Office | | 13.75 | 13 75 |
| " | 72 | Gasoline and Acid | 1 30 | | 1 30 |
| | | TOTALS | 98 50 | 78 65 | 177 15 |
| | | COST PER Bond | .523 | .416 | .942 |
| | | " " Ft of Single Track | .038 | .031 | .069 |

Bonds used - Chase Shawmut Type BB 4/0 capacity. Those at 31 each were purchased locally.

Const Dept Note :- Cost too high a/c city permitting us to open up only 600 ft of track at one time. Work therefore done piecemeal.

C.H.L.

The Armour Engineer

FIG. 5. UNIT COST RECORD

all matters are fresh in the superintendent's mind, and he is sure then that the cost data his accountant hands him from time to time is correct.

Whether or not the firm requires unit cost data in addition to the routine accounting records, the superintendent will be a more valuable man for knowing in detail what each part of his job is costing, day by day. If the accounting and time-keeping is properly done it adds very little either in cost or trouble to have such a record. A loose leaf Unit Cost Record is maintained by this company on all except the most complicated reconstruction jobs where the conditions are never likely to be duplicated. The sheet reproduced (Fig. 5) shows the cost in a Texas city of bonding 2,550 ft. of single track which was rebuilt when the street was paved. The value of such data to the Home Office in estimating future work is great, but it is vastly more useful to the superintendent who knows every detail of the conditions which influenced the costs, and who knows, therefore, even better than the office, just how much a dollar will do.

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There is no need for a recital of the many merely routine methods such as are found in almost every constructing engineer's office, and space has been given to only these special features which are out of the beaten track and which may prove of interest because they have increased the mental and executive efficiency of a considerable body of men.

As a parting word,

**Plan your work,**

then

**Work your plan.**

# EQUIPMENT OF REINFORCED CONCRETE FACTORY BUILDINGS.

By MORRIS W. LEE, M. E.*

The use of reinforced concrete for factory buildings is rapidly increasing in favor, and while the actual construction details have been quite thoroughly worked out and the difficulties of such a radical departure from former building methods fairly mastered by designing engineers and contractors, yet the matter of equipment for manufacturing purposes still presents a considerable number of problems.

One is apt to think, if he has not already had the experience which proves the contrary true, that with a factory building entirely completed by a contractor, the question of equipment consists only of the purchase of the required machinery and its installation, with the necessary power to run it. This is of course true, but the word installation, with the numerous et ceteras which it involves, proves to be a more comprehensive term than is at first considered.

The general methods of equipment and installation in the mill construction type of factory buildings, like the building methods for these structures, have been well developed and do not present new difficulties to any great degree. With the reinforced concrete buildings, however, this is not yet the case, and it is the purpose of this article to describe some practical examples of equipment in this type of building.

The matter of equipment is involved in the construction process to some extent, and must necessarily be considered with it. That is, the matter of floor space, department distribution and the character of the work to be done, determine the size and proportion of the building. Insurance provisions determine whether or not sprinklers shall be installed, and provisional floor layouts of the machinery call for certain arrangements for power and light distribution. In some particulars the details can be worked out before-hand and exactly adhered to, but for the most part, changing opinions and developing conditions serve to alter, in some degree, original plans for installation.

Starting then with the principal items to be considered before or during construction, we find them to be Heating and Ventilating, Power Application and Distribution, Illumination, and Fire Protection.

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*Class 1899. Chief Engineer, Keuffel & Esser Co. Hoboken, N. J.

One other thing which comes under the classification of items to be considered during construction is the lighter partitioning. This is true for the reason that modifications are not easily made in a concrete building after the forms have set, for in this style of building it is a question of dealing with steel and stone, and not a mere matter of altering a wood partition.

The unyieldingness is, in fact, the distinguishing difference between the reinforced concrete and other types of buildings and it is a difficulty that the equipment engineer is constantly confronted with.

The placement of partitions should therefore be looked after with considerable care in going over the plans with the architect, to avoid the expensive and inconvenient alterations. In many cases the hollow tile or expanded metal with a plaster coat serve well for partitions, and they can be built in at any time with comparative ease. Wood partitions are also possible, but must have their upright posts suitably anchored to the concrete, to avoid their loosening from the inevitable shrinkage of the wood.

In the matter of heating and ventilation there is far from a unanimity of opinion as to the best transmission of concrete walls. This is largely due to the different mixtures of concrete used in various buildings, together with the variable quality of workmanship in tamping the concrete in the forms. Either of these conditions, or the combination of them, produce walls of differing conductivity. In figuring for the amount of heat required, therefore, it is well to take the heat transmission of first class concrete through the walls as 1¼ to 1½ that of brick walls of the same thickness, and to figure an accordingly larger proportion where the concrete is of poorer quality.

There is also a difference of opinion as to the duration of the "drying out" process of concrete walls, some maintaining that these buildings are harder to heat during the first winter because the drying out process is not completed before that length of time. It is the writer's opinion that when a concrete building is put up in cold weather, the water may not all crystallize or evaporate, and thus the walls may retain their moisture for some time, but if put up in moderate or summer weather, there is little or no dampness retained.

The ventilation problem depends upon the character of work and number of workmen per cubic contents, as well as on the character of the structure. The window leakage is ordinarily less in a concrete building, and this in a measure offsets the transmission losses through the walls, but the mod-

ern tendency is to increase the percentage of glass surface to outside wall, and with it the window leakage. In the average building, if the proportion of workmen to cubic feet of contents does not exceed 1 to 1500, forced circulation is not called for unless the air is vitiated by something in the process of manufacture. With some buildings, the peculiarities of plan or deficiencies in structural tightness permit of an abundance of ventilation by leakage to care for one man to less than 1,000 cubic feet contents.

The writer's judgment is that the forced air or hot air system of heating is not so satisfactory nor economical for factory purposes, as the direct heating system. With the hot air or indirect system it is often the case that unnecessary quantities of cold air are drawn into the building and there heated at the expense of considerable fuel. This hot air is then forced on the workmen in a dry uninvigorating condition, so that the result is less satisfactory than that attained by the use of a direct heating system with the ordinary leakage of fresh air from outside constituting the ventilation.

The question of power application is one of wide variety and should be developed with regard to the particular work to be carried on in the buildings after their completion. In that section of the factory which the writer has principally under consideration, the power is electrical, produced in a central power plant and distributed both through individual motors and group shaft drives. Here the plan for main feeders was laid out as the concrete work progressed, and suitable openings left in the floors for the passage of conduit which was to carry the main circuits. As it was decided to have all open wiring, no pipes or conduits were laid in the floor slabs except in a few places where concealed work was necessary.

If the main plan of such wiring can thus be laid out, considerable work in cutting and drilling can be saved, and the smaller details developed after the completion of the building. One objection to making a complete detail of floor and machinery layouts, before or during the construction of a building, especially where individual motor drives are used and the wiring is to be drawn through pipes laid in the girders or floor slabs, is that the arrangement is almost invariably changed after the completion of the building. The conduit locations are then inflexible for needed alteration. For this reason it is better to lay out the main lines, with a provisional plan for the details, but allow for open wiring, which permits of ready alteration, to meet developing conditions.

Good illumination is a vital point, and demands careful

consideration as to the kind required for the particular work in hand. It is undoubtedly true that good illumination is a good investment, resulting in increased productiveness of the employees, or more accurately speaking, poor illumination serves to cut down production.

The principal types of lamps suitable for factory illumination are the arc, either plain or with concentric diffusors, the ordinary incandescent, the Nernst, the mercury-vapor and more recently the tungsten incandescent. Until the tungsten lamp is made cheaper and less liable to breakage from vibration, however, it will not be largely used in factory illumination.

When providing for any of these, or a combination of them, the same general remarks on flexibility as about power wiring hold true, though the illumination scheme is less likely to suffer changes of an extensive character than is the power distribution plan.

In bringing up the matter of fire protection as one to be considered before or during construction, the unburnable character of the building naturally suggests itself. The building contents are nearly always combustible, however, and for this reason the owners often install a complete sprinkler system, either as a result of their own judgment of because of insurance regulations.

Many times no provision is made for sprinkler pipes until the building is completed, and this entails a considerable amount of unnecessary labor. The insurance companies requiring sprinklers, or prospective contractors to install such work will always give sufficient information to determine where the sprinklers should come, and thus provision for supporting the pipes may be made during construction.

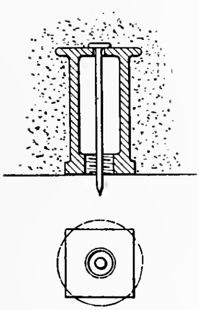

Fig. 1.

The method pursued in the Keuffel & Esser Co. factory buildings was to set an anchor in the beam forms and concrete around it. This anchor, as shown by Fig. 1, resembles a spool, the upper flange being round, and the lower one square, as an additional safeguard against turning when screwing in the hangers. The anchors were tapped in the bottom before setting and the thread was to receive the pipe hangers later. Considerable care must be employed by the builders in setting these anchors in order to get them

properly in line, and they must not be misplaced in ramming the concrete in the beams. To prevent displacement, a wire nail was driven through the spool into the bottom of the beam form. When the form was removed, this left the nail point projecting slightly, but this was no disadvantage, as the hangers were of 3/8 in. pipe and the nail entered the center of the hanger. The dimensions for setting these anchors were given to the builders floor by floor as they progressed, and so accurately were they placed that in only a few cases was it necessary to do drilling to provide additional supports. Fig. 6 shows this arrangement on the paper stock floor.

Where such previous provision is not made for hanging the pipes, the customary way of supporting them is by an eyebolt hung on an expansion or through bolt drilled for and set in the beam near its upper edge.

It may be noted here that if holes are to be put through the floor beams, the best place to put them is slightly below the floor slab, i. e., near the top of the beam, as this is about the neutral axis.

Returning now to items of equipment installed after the completion of the building proper, a brief description will be given of the conditions prevailing at the Keuffel & Esser Company factory, as this is the one to which particular reference will hereafter be made. This factory covers a large portion of two city blocks and is divided by a 65-foot street, all of the concrete buildings with the exception of the boiler house being on the same side of the street.

The power and light lines for these buildings consist of 5 pairs of 700,000 C. M. lead sheathed cables running from the switchboard in the engine-room in clay conduit, through the factory yard, and under the street through individual iron conduits enclosed in a large cast iron pipe. They go to 5 risers, one in the general office and warehouse building, and four in the main manufacturing building, where they pass through distributing panel boxes on each floor.

In order not to have wires running from the ceiling to the individual motors scattered through the floors, the distributing boxes are arranged so that a main power circuit from each leaves the bottom of the panel box and runs under the floor on which the box is placed. All the branching of the power lines in the groups of motors controlled by the various panel boxes, is done on the ceiling of the floor below, and the motor connection made through an iron pipe conduit run through the floor slab directly alongside the motor.

The lighting lines for each floor go out the top of the panel box and run on the ceiling of the floor they are to illuminate.

Thus the space around all motors is free from entangling wiring or conduit, and yet both power and light are controlled at the floor on which they are used.

Under the first floor the fuse-blocks and cut-outs are all enclosed in iron boxes with tightly closing doors. This is done to protect the metal connections from dampness and corrosion, as there is no basement and the moisture under the floor is at times considerable.

The plan of illumination adopted was to hang incandescent lamps at each machine and bench, so that practically every employee has a light placed directly where he is working. This individual illumination is supplemented by a sufficient number of arc lamps to produce a general illumination adequate at any point for the rougher processes or for moving material from place to place.

All the power wiring is carried in porcelain cleats and the light wiring on knobs. The difference between wood and concrete construction is very strongly emphasized in this wiring work, because for every screw that holds a cleat or knob, a hole must be drilled from 1 in. to 1½ in. deep, and this hole plugged with a wooden dowel which then carries the screw.

It may be readily seen that this labor is considerable, but it is not necessarily expensive. One competent electrician had charge of a group of laborers, and laid out the position of every knob or cleat with its corresponding screw hole. It was found that he could easily lay out work for a number of laborers and supervise them at the same time, and thus good progress was made at small expense.

An ordinary star drill and hand hammer were used for drilling, and enough extra drills were obtained, so that a lot could be in the blacksmiths' hands right along for sharpening. It does not pay to use a dull drill for long.

Practically all of the power wiring was done before the lighting, as the machinery was installed during the summer months when hardly any light was needed. The plans for the power wiring were worked out carefully for the size of wires, cut-outs, etc., and if the location of a motor was changed from that first proposed, an alteration in the direction of the wiring from that given on the plan was all that was necessary, as the sizes ordinarily remained the same and there were no inlaid conduits to be followed. The lines were run between the bays or along the girders as much as possible, to avoid breaking around the corners. The straighter the run, the fewer cleats required, and consequently fewer holes to be drilled. In some cases the lines were run spanning the beams, with a cleat at each beam.

The plans showing the exact location of every light were made in the following manner: Diagrams were made of every floor, showing all desks, machines and benches, as well as the position of columns and ceiling beams. These were then taken on the floors, where each foreman was consulted as to the exact location of lights required. These were noted on the blue print and subsequently incorporated in the plan. There is a decided advantage if this method can be pursued, as in many cases one can tell much better from what direction or in what position a light should come, when the actual working conditions are in evidence, than from consideration of a floor plan alone.

In laying out the lighting lines, the effort was made to bring the principal lines directly over as many required drop positions as possible, in order to save wire and drilling in side connections, and it was found that by careful consideration of the conditions in most cases this could be done. Where side branches were required only a short distance from the main, the rosette was put on the main line and a reinforced cord carried to a ceiling button to drop a light where wanted. This called for only one screw and saved a splice and several holes.

It may be seen that to run the lighter gauges of required lighting wire the length of the buildings in two or three lines, would necessitate breaking around several hundred concrete beams from 4 ft. to 5 ft. apart, and this meant an enormous amount of drilling. It was therefore decided to use a gauge of wire sufficiently large to come within the insurance requirements for wiring bridged from beam to beam. This was in many cases a much heavier wire than needed for the current carried, but while heavier, it was also much shorter on account of its directness, and could be put up more quickly and easily. The use of heavier wire therefore actually effected a saving.

Many ways were considered for avoiding the necessity of drilling for the two screw holes found in all the types of rosettes, and the scheme shown in Fig. 2 finally adopted in conjunction with the method of wiring just described. A hardwood block the diameter of the rosette was made of sufficient thickness to bring the rosette connection to the same height that the knob holds the wire, and this block was drilled for a center screw and dipped in white paint before it was fastened to the beam. The knobs were spaced to bring the main wires the same distance apart as the rosette connections and placed off the center of the under surface of the beam. The wood blocks were fastened alongside these knobs, so that after the lines were strung, the rosettes could be fastened to the blocks and their connections line exactly with the wires, which were bared at these points to make connection.

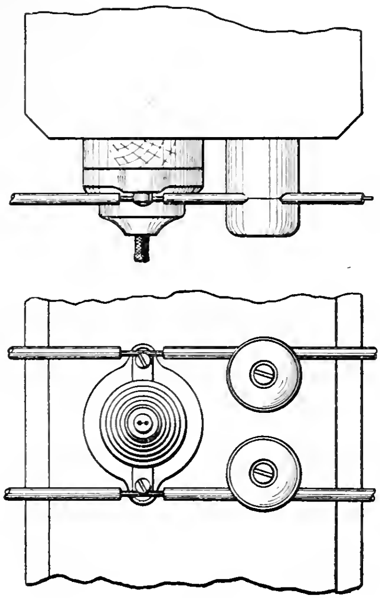

FIG. 2.

Thus by the use of three holes in the beam, the two knobs and the rosette were held in the most convenient position and one drilled hole saved for every rosette, as the two screws from it fastened in the wood. When finished, the job presented a very neat appearance, and one would not know except from close examination that anything besides porcelain had been used.

As far as possible the lights were dropped from beams in this manner, and where one was needed in another spot, the rosette was put on the beam and a cord carried through a ceiling button to the required location. All knobs were set to one side of the under surface of the beam to allow for a future light connection. By running such a line the length of each bay, thorough provision for alteration is made, and a light can be easily dropped at any spot where it is later needed.

The direct system of steam heating was employed, with the steam pipes mostly at the side walls under the windows. The wall coils were hung in pipe racks screwed to wood battens which were fastened to the walls by expansion bolts.

In placing the individual motors, economy of space, together with proper length of belt drive, was carefully considered. In the case of circular saws, sanders, carvers, and jointers, the motors were placed on the floor; and where needed, suitable tables or frame work set for their protection. In many cases, notably with planers, the motors were suspended from the ceiling, with pulleys at each end of the armature shaft.

Where the armature shaft itself was not long enough to give the proper span between the pulleys, this was obtained by extending the shaft and setting a hanger to support the extended end. Fig. 3 is an example of this style of drive.

In some cases a modification of this plan was required because of some very fast running pulleys and some slow running, which are ordinarily taken care of by a countershaft. As an example of such a drive Fig. 4 shows a sander where the three sand rolls are driven by a single belt from the main motor pulley and the feeding mechanism driven from a countershaft run from a smaller pulley on the other side of the motor with extended shaft and hanger. It will readily be seen that these suspended drives are very economical of floor space, and also allow freer access to the machines than floor stands or floor motor drives.

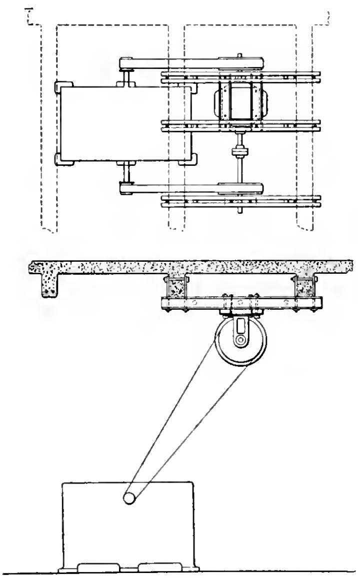

FIG. 3.

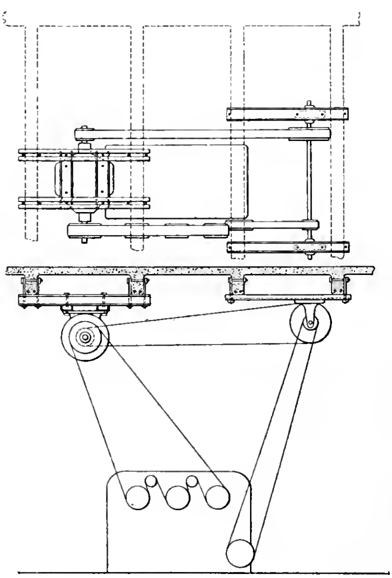

FIG. 4.

All suspensions for motors and shafts were made of iron and steel instead of wood. Angles, I-beams, channels or their combinations were employed as best suited to the conditions, and where heavy weights were carried, a double channel with riveted spacing blocks was found very convenient for attaching.

The advantage of iron and steel supports over wood is considerable. First, they are more rigid for the space occupied; and second, they stay rigid, whereas wood does not.

It is not necessary to take up on the bolts continually as is the case with wooden supports, which are sure to shrink for a considerable time after they are set in place.

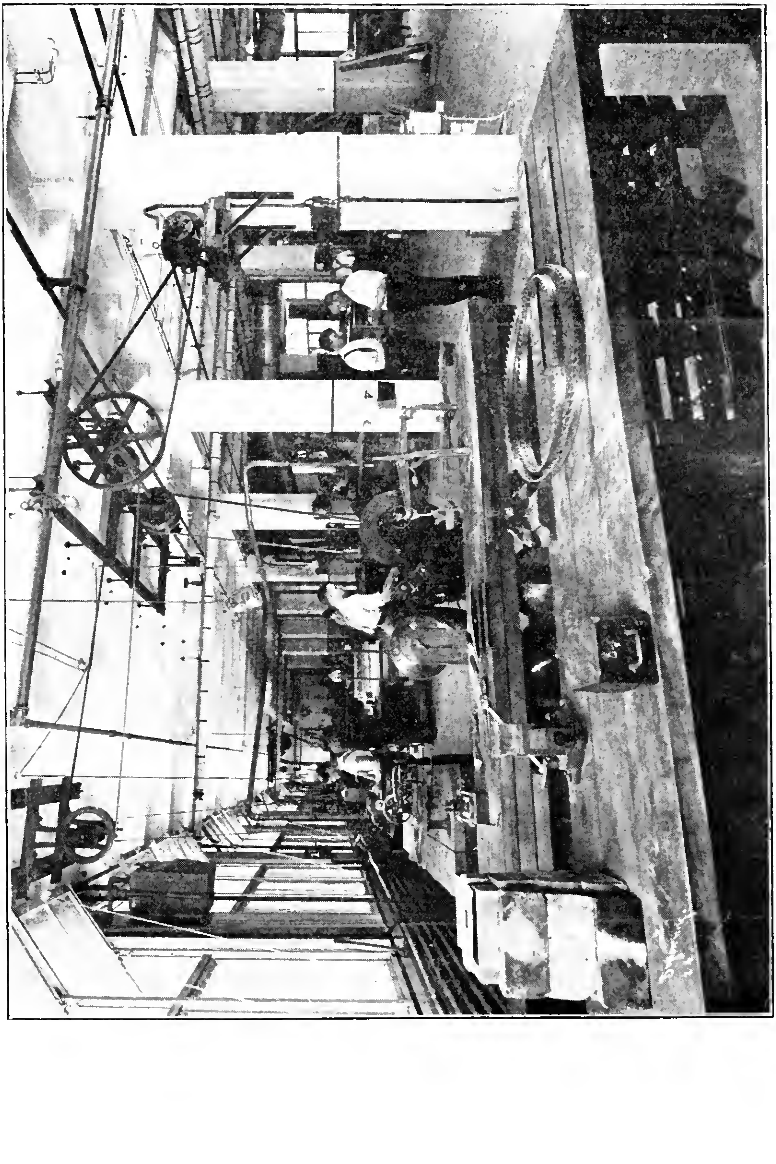

Fig. 5. Interior View showing Equipment Details.

Where several small machines could be grouped together, they were driven from a short shaft with a single motor. For supporting the hangers two channel irons were attached to the beams by eyebolts hung from other bolts through the beams. This method of running the channel irons the full length of the shaft allows the hangers to be set in any location by merely drilling the iron, and is thus a more flexible construction than where hangers are fastened individually to the concrete.

The motors for driving these shafts were set on brackets to provide more floor room. A good idea of this style of group driving is shown in Fig. 5, where several small machines are driven from one shaft and the motor is against the column. The iron pipe running up the column to the starting box shows the method of conveying the power feed from below.

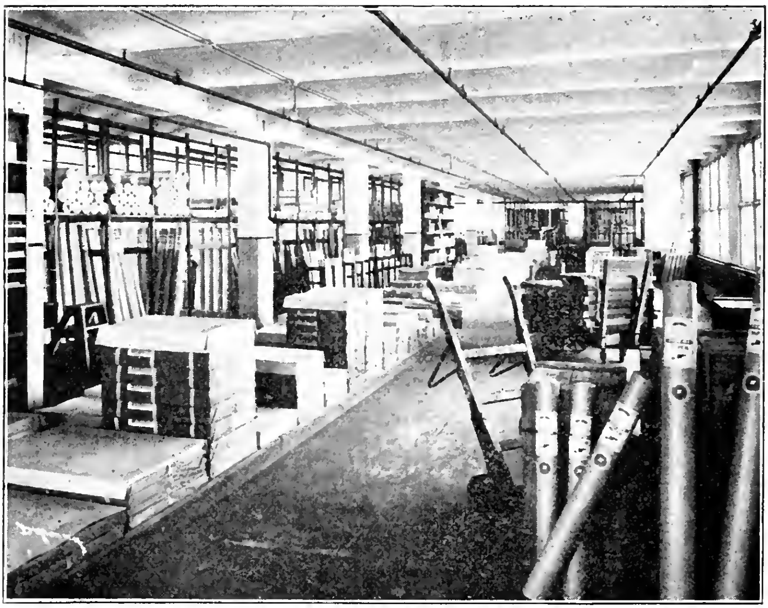

FIG. 6. VIEW IN PAPER STOCK ROOM, SHOWING LIGHTING WIRES AND SPRINKLER SUPPORTS.

One other equipment item in the Keuffel & Esser Company factory is the dust and shavings collecting system, for the three woodworking floors. The general plan for this is an

independent direct motor-driven blower on each floor discharging into one large collector on brackets outside the building. This separation into floors avoids the necessity of cutting large holes in the floors, and is more acceptable to the insurance people also.

In making the individual exhaust connections to machines, the pipes were carried to the ceiling wherever possible. In some cases where a bottom connection was necessary, the pipe was run on the floor to an adjacent column, where it was carried upward to the main pipe. In the case of the circular saws which are placed in the open and should have clear space all around, it was necessary to cut a hole through the floor directly under the machine, run under the floor and rise at the nearest column to meet the main ceiling line.

The three fans on the different floors are mounted directly on the armature shafts, which were ordered specially for that purpose. This eliminates the fan bearings as ordinarily installed, as well as possible mis-alignment of fans and motor shaft. This arrangement and the separation into groups has been found very economical of power. The motor and blower are suspended from the ceiling in an iron cradle which, as before mentioned, has the great advantage of floor space saved and permanent rigidity.

In conclusion it may be said again that the unyieldingness of the concrete construction is the feature which stands out most prominently in the task of equipping such a building, but this very fact is in itself an incentive to install a more permanent and reliable type of equipment, and to build better than before.

## AN INEXPENSIVE FIREPROOF HOUSE.

### BY HORACE S. POWERS.*

Building in some form of concrete material has, in the popular mind, become nearly synonymous with fire-proof construction in the smaller class of buildings and dwellings. Many of the writers of today in speaking of progress in the use of concrete have gone so far as to call the present an "age of cement" and as one looks around and reads in technical journals of things which have been accomplished with this material in the form of concrete one must realize that such a term is becoming justifiable if it is not so already.

There seems to be no end to the uses to which this material can be put. It is a far reach from the vast engineering projects being pushed in many different localities to the beautiful garden furniture which is being made to ornament lawns and gardens of our modern homes. Great canals are being lined with concrete while even boats are being made to float upon their waters.

In the writer's opinion, the use of concrete as applied to the larger and more important classes of buildings and even in the smaller buildings where cost is a secondary consideration, will continue and even drive out of use other forms of fireproof construction now used. With several years' experience in the smaller type of buildings it has been found that solid or monolithic construction of walls and floors is made unwarrantably costly by the expense of building the wooden forms as in a small building the cost of building these forms must necessarily be larger in proportion than in the larger buildings.

Many architects and many builders are experimenting in different forms of portable units of reinforced concrete for floor construction, which, taken together with a satisfactory form of hollow blocks in wall construction, should lead to a practical as well as an economical type of buildings. Several forms of portable "joists" made of reinforced concrete, have been placed on the market, but as yet have not been tested out. These joists are so formed that when set in position they form a portion of a continuous floor, while others are arranged to form also a continuous ceiling. These joists are economical of concrete and also of reinforcing material and have been made of great strength. The type of hollow concrete blocks which show a uniform "rock-face" pattern on each block is recognized by all architects and lay men alike, as giving

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*Class 1899. Spencer & Powers, Architects, Chicago, Ill.

a result which is an eye-sore even if same is a good type of wall construction. With a flat-faced block which is bush-hammered after erection a pleasing exterior can be obtained or flat-faced blocks may be cast in moulds to imitate what is known in stone cutting as tooth-chiselling. If the courses of such walls are laid up with varying heights arranged to give a decorative effect an attractive result can be obtained. No matter what design is given to the exterior of such blocks or even to obtain a satisfactory appearance in solid concrete, the materials composing the concrete must be selected both in the cement and in the aggregate, as no color is more disagreeable in a wall than the natural cement color.

FIG. 1. FRONT VIEW OF HOUSE NEARLY COMPLETED. CONCRETE ON ROOF OF PORCH, GUTTERS AND DOWNSPOUTS HAVE NOT BEEN INSTALLED.

We see many references in the public press to the " Edison Idea " of concrete construction. As the writer understands this method it is proposed to build forms for a complete house in steel and iron, even going so far as to shape in these moulds the bath tubs, wash basins, cook stoves and possibly some of the fixed furniture which will be forced along with the walls and floors when the concrete is poured into the moulds.

As a set of forms for each design will cost in the neighborhood of twenty-five to thirty thousand dollars, it necessarily follows that several hundred houses or buildings must be built from one set of forms before this type of construction becomes economical and the prevalence of such method of building will result in whole streets, even towns, being built with all the houses exactly alike, which would certainly be most unfortunate. Much attention is being devoted at present to obtaining characteristic and individual houses which fit their sites and occupants.

Another influence leading to the extensive use of concrete and other fire-proof materials is the fact that the lumber which we are now obtaining for use in our buildings is steadily increasing in cost while at the same time its quality is decreasing and today we are using lumber which ten years ago would have been considered fit only for kindling wood.

With these facts in mind, a firm of which the writer is a member, has been endeavoring to find a method of building which though perhaps not entirely fire-proof would lead to the use of fire-resisting materials. It has been found that the use of a combination of various materials is cheaper at present than the exclusive use of concrete.

The house which is illustrated in this article is a result of an experiment by this firm and a progressive builder and owner, Mr. A. Baxter, and was built in Park Ridge, Illinois. Although not entirely completed, the work is so far done that the cost can be determined. The outside walls of this house were built of 12 in. x 12 in. x 8 in. hard burned partition tile with double air spaces. The tile below ground were glazed and all were laid in good Portland cement mortar. Over the larger window openings the tiles were laid with webs running horizontally and were filled with concrete with a couple of rods run through the lower spaces, thus forming concrete beams encased in the tiles. Cement base course was run around the building at the top of the ground. Window sills were covered with a tile which is ordinarily used to cover flat roofs. These tile are 6 in. x 9 in. and 1 in thick, and were set at a sufficient angle to give a good water shed, projecting about an inch from the wall. As these tiles have a soft light red color, the sills give a needed color touch. Outside the tile wall was plastered with two coats of plaster, first coat being of good cement mortar trowelled to a comparatively smooth finish and thoroughly scratched. The plaster was also carried around on the reveals of the windows, giving the house a good masonry look. Over this first coat was applied a specially prepared plaster which came to the job ready mixed and only needed the addition of

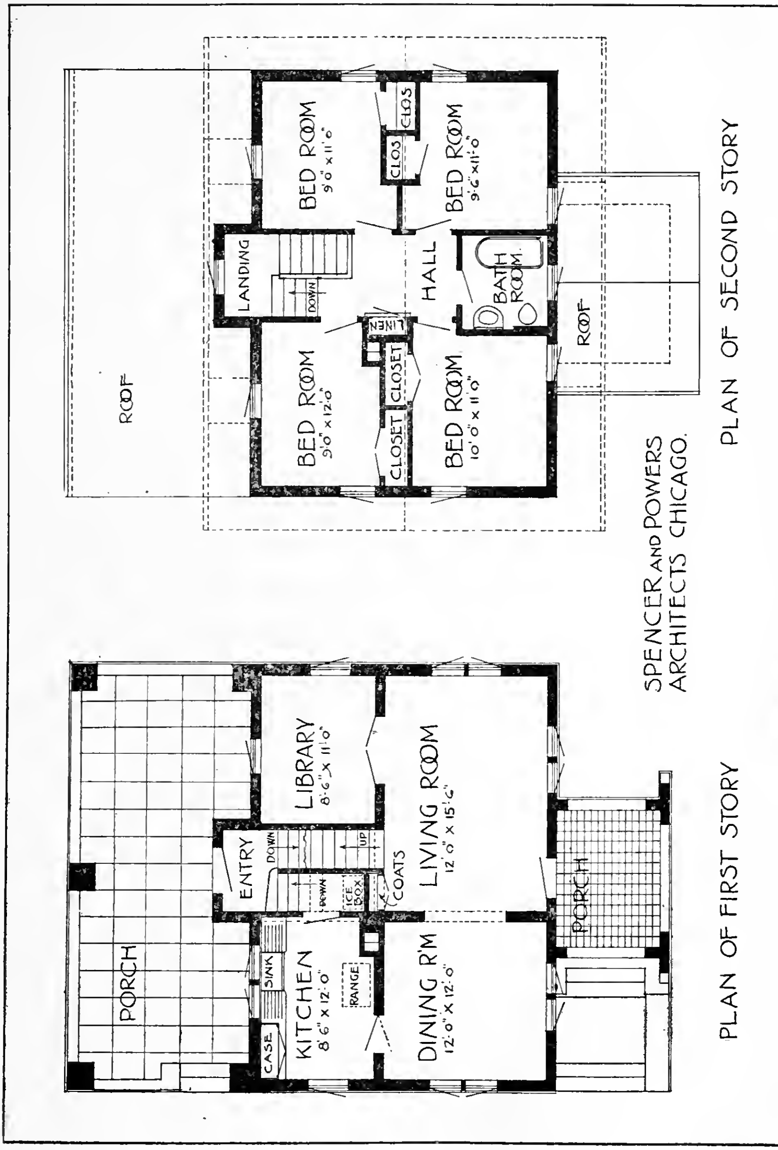


Fig. 2. Floor Plans.

water to be ready for putting on the wall. This last coat of plaster was applied as a rough cast coat and was thrown from paddles in a semi-liquid form. This plaster was also waterproofed at the factory and was obtained in a light ivory color.

The use of this prepared plaster does away with much worry on the part of the architect and also of the contractor, as to whether the color of the finished plaster will be a happy shade and have a uniform tone.

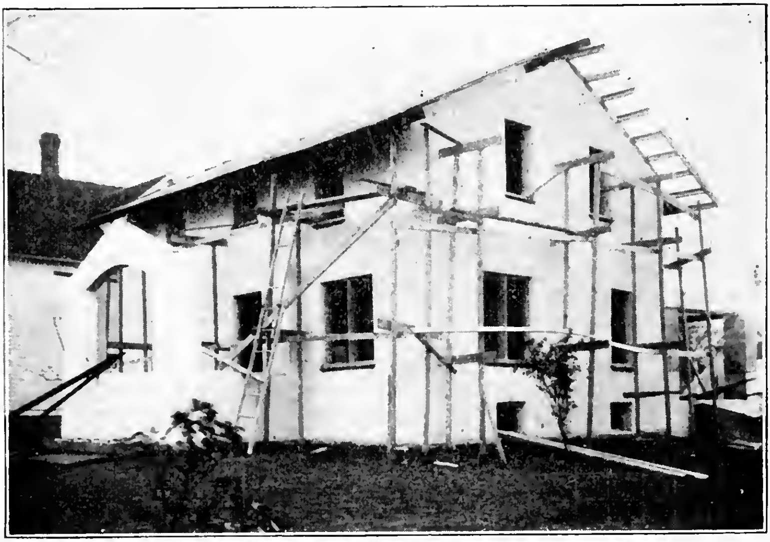

FIG. 3. FRONT VIEW DURING CONSTRUCTION, SHOWING ROOF CONSTRUCTION BEFORE CONCRETE WAS APPLIED.

To obviate the expense of building forms for concrete floors or even concrete girders, a material for floor and roof construction was adopted, which is a form of "metal lumber," so-called, which is manufactured in Canton, Ohio. This "lumber" is composed mostly of I-beam and channel shapes. The I-beams consisting practically of two channels riveted together back to back. The metal used in this lumber varies from 16 to 18 gauge, and the lower flanges of both I-beams and channels are punched at intervals of 8 to 10 inches to form a sort of prong which projects downward vertically from the face of the flange so that metal lath placed against the flanges can be secured to them by simply bending over and hammering down these prongs, which is very quickly and easily done.

With a set of heavy tinsmith's tools, such as shears and punches, these I-beams and channels can be framed together quite readily with little experience.

The first and second floors of the house are carried on metal I-beam joists of this kind, placed 16 in. on centers. The interior bearing walls carrying the first and second floors were built of 8 in. tile similar to the outside walls of the house. The roof was framed in a similar manner to the floors, using a channel instead of an I-beam shape for the rafters.

FIG. 4. REAR VIEW DURING CONSTRUCTION, SHOWING CONSTRUCTION OF REAR PORCH.

Even the makers of this new material did not seem to know positively just how much could be figured for a safe load and in this instance the channels proved a little too light to carry stiffly the concrete slab of the roof and in another building of this kind the use of I-beams for rafters would be recommended.

On top of the metal channel rafters a corrugated sheet metal plate was used upon which a concrete slab 2 in. thick was installed. This 2 in. concrete slab was composed of a good cement concrete of ordinary materials and upon this was placed a finish cement coat of specially prepared cement plaster colored to a reddish brown tone and water-proofed by the addition of a patent water-proofing compound. This

was floated on the roof to a reasonably smooth but not a glossy finish. The underside of the corrugated metal forming the support, for the concrete roof was capable of holding plaster underneath and was plastered between rafters. To avoid cracking of the concrete of the roof from expansion and contraction due to changes in temperature, two joints were made running up and down the roof on each side. The edges of these joints were raised to shed water away from the joints and the joints carefully caulked with oakum and filled on top with a water-proof compound.

FIG. 5. VIEW IN BASEMENT, SHOWING CONSTRUCTION OF FIRST FLOOR. NOTE METAL JOIST AND BRIDGING.

The photographs taken in the basement and second story of the building, reproduced herewith, show examples of metal I-beams used in the first floor and channels used in the roof constructions. They also show the corrugated metal used for carrying concrete roof slab. The method of metal ribbon

bridging used to tie the rafters and joists together is also shown. Photographs of the building made during progress of erection show the roof construction in the main roof of the house and of the porch on the rear.

For the structural members of the partitions in the second story a new form of stud was used, made of plaster material in sizes about 3½ inches square, having a core about 1 inch square of wood to give to the plaster the necessary tensile strength. These studs have been found satisfactory. To these studs a plaster board was nailed, on which two coats of hard

FIG. 6. VIEW IN SECOND STORY, SHOWING CONSTRUCTION OF ROOF. NOTE METAL RAFTERS AND CEILING JOISTS, AND CORRUGATED METAL CENTERING CARRYING CONCRETE ROOF SLAB.

plaster were applied. A little better wall, probably not very much more expensive, would have been obtained by the use of metal lath nailed to the plaster stud. The inside of the outside walls was plastered directly on the tile. The ceilings

of the first and second stories were finished with three coats of hard plaster applied to metal lath secured to the joists and rafters by making use of the prongs already described.

As the I-beam joists in the floor construction were double, wood floor strips were nailed to them by nailing into the joint between the two parts of the joists. To these nailing strips a rough floor of matched boards was secured in the usual manner. On top of this rough floor, finished floors of oak or maple were nailed after laying down two thicknesses of heavy deadening quilt in the same manner as wood floors are laid in a frame house.

The floor of the front porch is also carried on metal joists on top of which corrugated metal centering was placed to carry a concrete slab on which tile similar to tiles used in window sills was laid in cement mortar. The floor of the rear porch is of cement finished concrete laid on filled ground.

The doors and windows and interior doorways were trimmed in the usual manner with narrow wood casings. The stairway from basement to second floor was built up with "metal lumber" and corrugated metal centering and formed in concrete. This concrete was stained and painted with specially prepared material for this purpose.

From this description it can be seen that the only combustible materials used in this house were for the window frames, sash, rough and finished floors and the necessary window and door trim and built-in cupboards and cases. It can be observed from the accompanying illustrations and plans that though the rooms are small there are more of them than is usual in a house of this size, but the owner and builder claims that he could take a contract to reproduce the house, everything included, and at a fair profit, for $3800. This is but little if any more than the same house would cost if built in frame construction, using the same quality of outside plastering and interior finish.

In an experiment of this kind, one should always expect to find some places where better construction can be had, and another similar house is now being considered in which the outside walls and floor construction will be of the same materials, while the roof will be constructed of metal I-beams covered with a type of metal lath which has high ribs about 4 inches apart, designed in such a manner that these ribs give the lath sufficient strength so that a concrete slab with spans of 2½ or 3 feet can be installed without centering by first applying the concrete about 1½ inches thick to the top of the lath and afterwards plastering on underside about ½ inch thick. This concrete is to be composed of cinders and

cement. Cinder concrete is not only light in weight but has the property of allowing nails to be driven into it and affording good hold for same. Wood strips can thus be nailed to this cinder concrete and on these strips a tile roof can be applied quickly and with a comparative cheapness of cost.

Another modification to make a building still more fireproof, would be the installation of cinder concrete slabs on top of metal joists in floors on which can be laid some form of the many asbestos compositions now on the market which can be installed in very pleasing colors and make very durable floors. This would make a very sanitary installation, especially if a cove base were used in connection with same.

Another step toward the nearly complete omission of wood, would be the installation of moulded cement casings to be run by the plasterer around all doors and windows

If the statement of the builder can be credited, a house of this size in this type of construction can be entirely completed within six weeks should there be no delay in obtaining materials. The writer does not claim that this house is satisfactory in every way, but in his opinion with a year or two more in which to work out details and to give the workmen familiarity with the materials in hand, the future home builder would make a great mistake not to consider such a type for his building.

# THE MORGAN GAS PRODUCER INSTALLATION AT GARY

BY W. R. WILSON.*

It has been well said that the rise of the Gary Steel Plant is a great act of faith. It is faith in a single process to set aside over one hundred millions to construct on the sands at the southermost shore of Lake Michigan the world's greatest Steel Plant. Without parallel this seems in modern history, except in the fiat of Peter the Great to build Russia's capital on a morass at the mouth of the Neva. For fifty years now the Bessemer Process has been king in Steel making; it revolutionized this industry and through it all industry, and it holds undisputed sway when such items are considered as. first cost, cost per ton output, capacity per square foot of ground space, and capacity in tonnage per twenty-four hours. In the face of all this a great plant of sixteen blast furnaces to turn out 7200 tons of pig iron every day is being constructed without a single Bessemer Converter. Quietly a rival has been at work for the last thirty years until its supremacy in America is insured and now asserted. The supplanter is the Open Hearth Process invented by Sir William Siemens in 1856.

Nature it seems is against the Bessemer Process in America. The railroads, which, on account of their taking about 60% of the steel makers' product, are the steel makers' first consideration, have demanded a higher grade rail containing much lower percentages of impurities, phosphorous in particular, than was even supposed deleterious in the past. But while the railroads have raised their standard, Nature in America has lowered hers. The low phosphorous ores have been rapidly diminishing until now the limit of the supply is plainly in sight. This implies the relegation of the Bessemer Process, because it is unable to cope with phosphorous, except in smaller percentages.

The Open Hearth Process was patented in 1856 and 1861 by Frederick and William Siemens. In twenty years of indefatigable zeal the brilliant Sir William Siemens brought it into successful adoption about 1875. During those years he developed those distinguishing features, which since then have found improvement only in detail. The essentials of this process are four:—an individual fire box or Siemen's Gas Producer; a set of regenerative checker-brick chambers; an open

*Class 1906. Superintendent of Erection, Morgan Construction Co., Worcester, Mass.

hearth with reverberatory low-arch roof, and a chimney with proper flues and valves for directing the course of the gases. The last thirty years have not altered these fundamentals; their experience has served only in the development of each as a separate unit. In consequence, to-day we see the Gas Producers farther removed from the hearth and perfected both as units and as flexible systems of units; we have the regenerative chambers (four in number, two for air and two for gas) removed from their original position underneath the hearth to a place between the hearth and the producers.

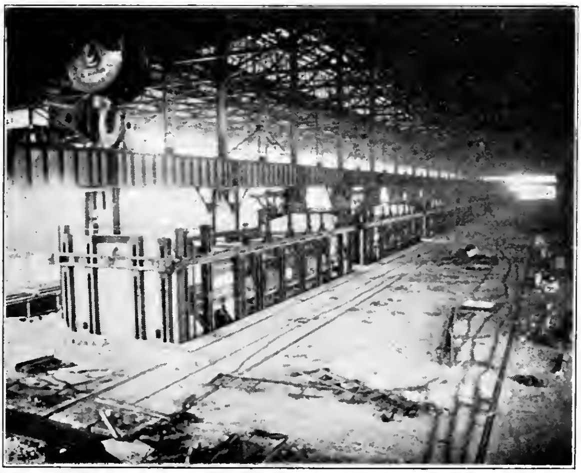

FIG. 1. VIEW OF NO. 4 OPEN HEARTH, CONTAINING FOURTEEN 60 TON OPEN HEARTH FURNACES.

Gary represents the highest development of Open Hearth design, though in some respects but little superior to the 21 million dollar plant of the Bethlehem Steel Co. a few years forerunner in the act of faith. The object of this article, however, is to examine only the Gary practice as to one feature—its Gas Producers, one hundred and forty of which have been installed on the first two Open Hearth plants by the Morgan Construction Co., of Worcester, Massachusetts.

Gas Producers in a very crude form have been used in Wales ever since coal mining began there, but Gas Producers and Gas Firing as an industrial process were initiated and developed by Sir William Siemens. Both oil and natural gas have been used for many years in Pennsylvania furnaces, but with the limit of supply in sight and the consequent rise in the

cost, Producer Gas has been proven to give more heating power and more gas for one dollar than any other fuel. It is interesting to note the points of departure in Producer practice between the ideas of Siemens and those embodied in the Morgan work.

The Siemens Producer had an inclined grate, air being admitted in front and below as in our boilers. The Morgan Producer is of the grateless type, with a bed of ashes resting in a water filled bottom pan as the foundation for the coal in the gasifying zone. The ashes are pulled out through the water from time to time by ordinary laborers with ash hoes, so that the gasifying proceeds continuously. To sustain the process coal is fed in at the top,either with hand feeds, or with George Paten Automatic Feeds. The latter give a mechanical distribution, saving as high as 10% in coal consumption. In these ways there need be no interruption in operation for 365 days in the year; no repairs in grates; no stoppage for cleaning out. The lining of fire brick with ordinary precaution should not need replacement in less than four or five years. Gas, uniform both in quality and quantity, is insured, as well as the automatic disintegration of clinkers.

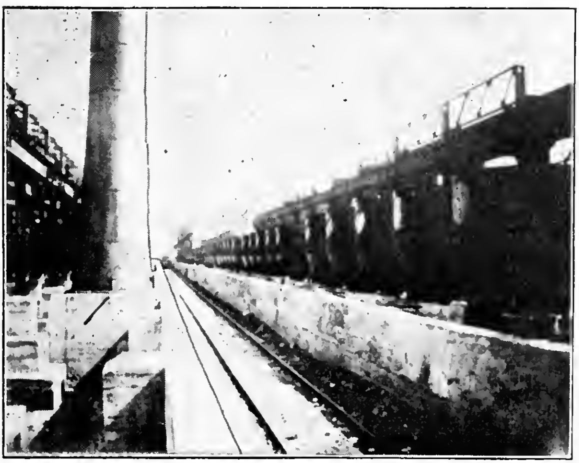

FIG. 2. A QUARTER MILE OF PRODUCER SHELLS ON FOUNDATIONS.

The draught in the Siemens Producer was obtained on the syphon principle of making two legs of unequal length in the gas flue, the farther from the Producer being the longer to give induction. This necessitated setting the Producers relatively

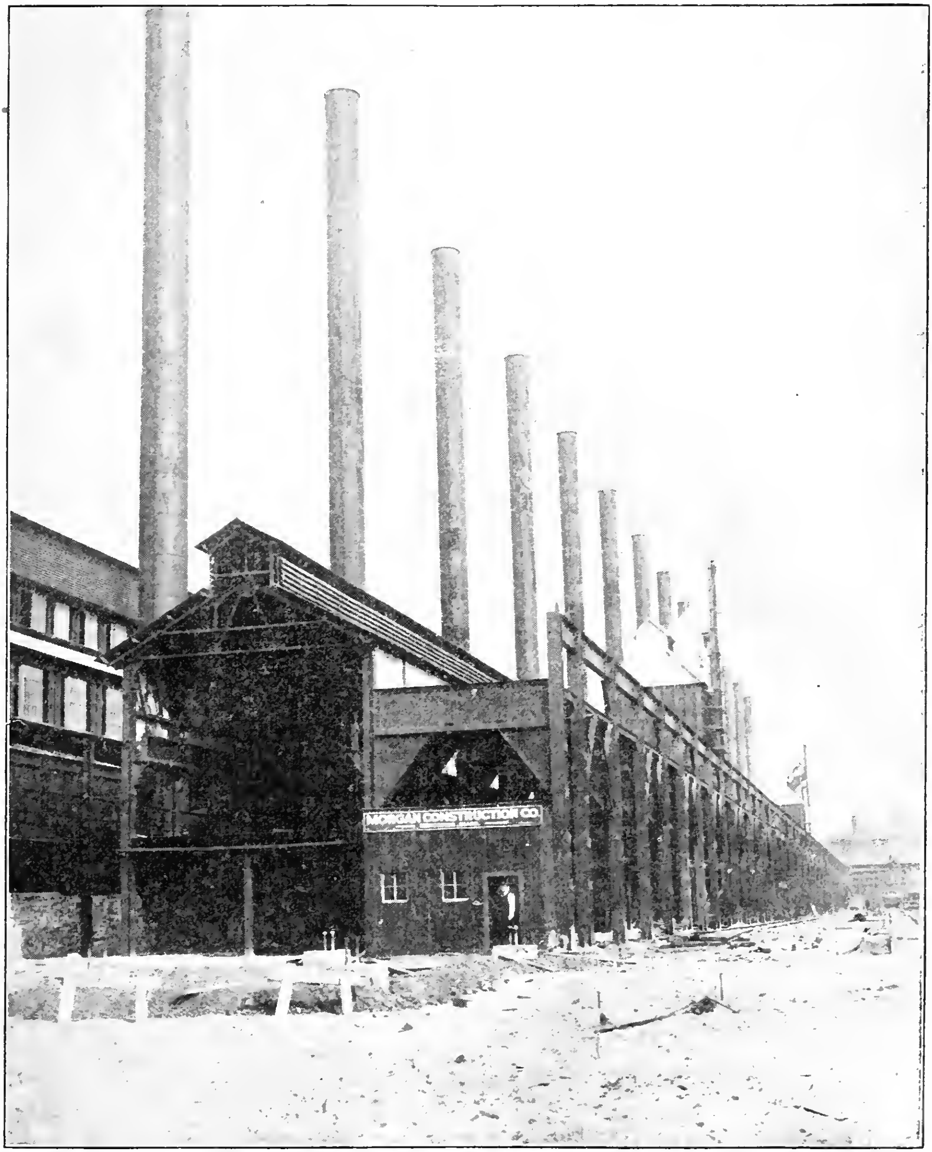


FIG. 3. OFFICE AND GAS PRODUCER BUILDING ALONGSIDE OF OPEN HEARTH PLANT.

higher than the furnaces. On the other hand the Morgan Producer is blown by steam and air introduced underneath in a big injector and distributed in an even blast throughout the fuel by a four-ringed conical hood centrally located inside. This makes it a pressure Producer. Steam is introduced with great benefit, principally, in diminishing the amount of nitrogen, which composes 79% of the air blown in; in giving combustible hydrogen gas in return for the heat absorbed in its separation; by enabling the Producer to work at a much higher

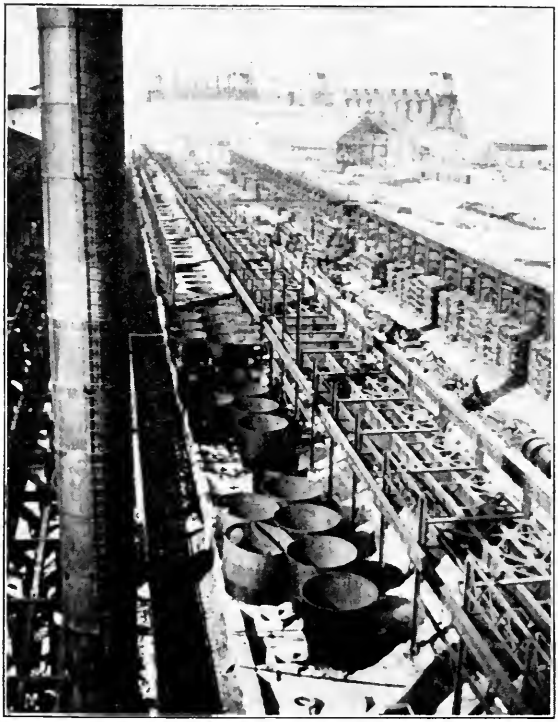

Fig. 4. Aerial View of Quarter Mile of Producer Shells on foundations.

rate without overheating; and lastly by softening the clinkers. 30 pounds of steam is used for every ton of coal gasified in twenty-four hours.It follows from this method of blowing that the battery of Producers is now placed lower than the furnace Hearth, so that, whether the chimney draught is operative or not, the gas will naturally rise.

In construction, the Morgan Producer consists of a cylindrical steel plate shell contracted towards the bottom, which extends into a water filled ash pan formed as a depression in the foundation. The shell is supported by four cast iron feet in the concrete of the ash pan. Between these feet the ash is withdrawn. At a height of about three feet above the water level in the ash pan a number of sight holes are provided around the circumference of the Producer. These enable the attendant to watch the zone of combustion and to correct any irregularity in its level. The lining consists of hard fire brick with a cushion of sand or cinder between it and the steel shell.

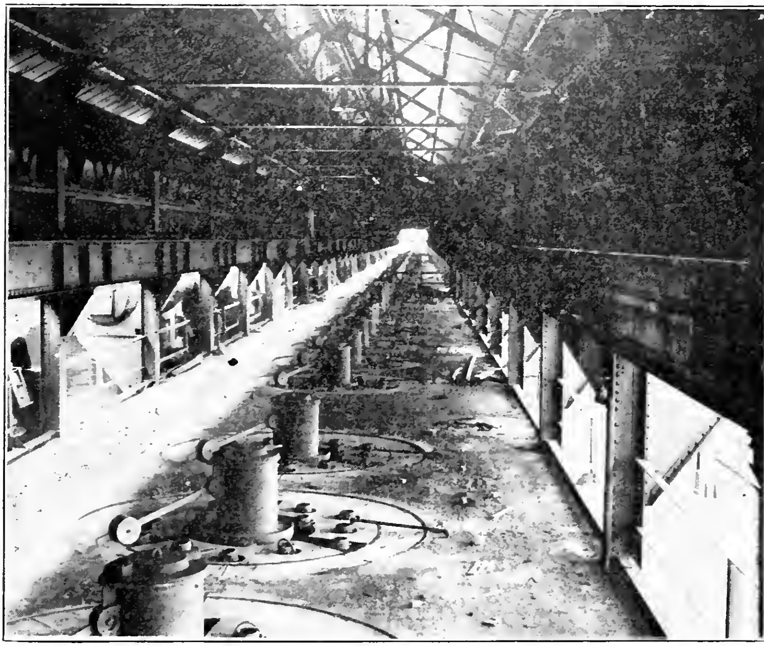

FIG. 5. VIEW OF SEVENTY PRODUCERS ON CHARGING FLOOR SHOWING HAND COAL FEEDS.

The top of the Producer is covered by a shallow open cast iron pan filled with water. Through a central opening in this the coal feeding apparatus communicates with the interior. Poke holes closed by water sealed covers are placed around the central opening. The height of Producer top above the foundation is 11 ft. 6 in.; the outside diameter is 12 ft. and the inside 10 ft. This is called the standard Producer, and at the rate of

10 pounds of coal per square ft. of surface per hour will gasify about one-half a ton of coal per twenty-four hour day. The large advantage of these proportions in the Producer are. to make the fire zone midway between the top and bottom of the Producer, thus giving a great uniformity in quality in the gas; and a wide range of gasifying capacity, running as high as 15 pounds of coal per square ft. of surface per hour.

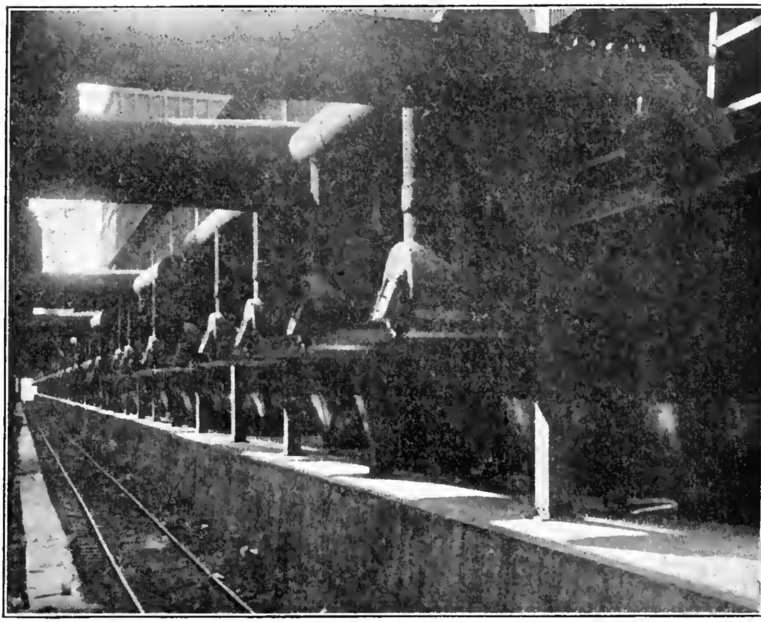

FIG. 6. A QUARTER MILE OF GAS PRODUCERS AND GAS FLUES SUPPLYING ONE OPEN HEARTH PLANT.

Gas is generated at the rate of about 60 cu. ft. per pound of coal with a heat value of from 150 to 200 B. T. U. per cubic foot. Its comparison with other industrial gases is evident when tabulated:

| | | | | |
|---|---|---|---|---|
| Blast Furnace Gas......... | 80 | to | 90 | B. T. U. |
| Producer Gas,.............. | 150 | to | 200 | B. T. U. |
| Coke Oven Gas,.......... | 450 | to | 550 | B. T. U. |
| Water Gas,................ | 600 | to | 700 | B. T. U. |
| Natural Gas, ............. | 900 | to | 1100 | B. T. U. |

The Gary installation of the Morgan Construction Company is the largest single Producer contract ever let, and consists of 140 ten ft. Gas Producers in two aggregations of 70

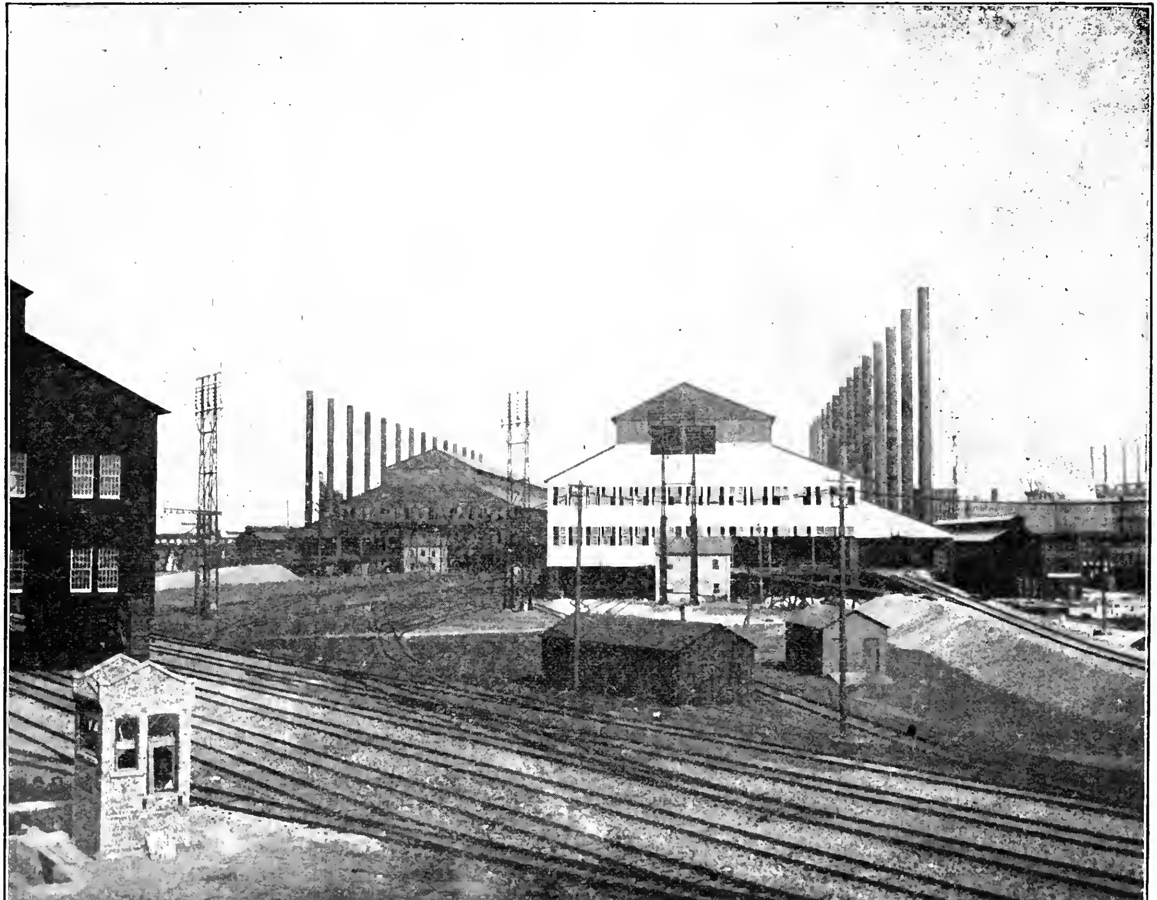

Fig. 7. Two Open Hearth Plants. Gas houses appear on the outer side of each.

each, supplying two great Open Hearth Plants. Each Open Hearth plant is the largest of its kind in the world, consisting of fourteen 60 ton furnaces. For each furnace a battery of five Producers is required. Their gas is led through a 54-in. gas flue into the Open Hearth building. The gas main there divides into two distributing pipes, each leading to underground flues, and thence to a Dyblie Gas Reversing Valve and into a gas regenerator chamber. The gas then passes into one of the two parts of an Open Hearth Furnace. The temperature of the gas leaving the Producer is about 1200 degrees Fahr., which is increased to about 2500° Fahr. in the regenerator. The whole current at the height of the melting operation passes through one regenerator fifteen minutes until reversal when it is diverted through the other one, which was heated up by the outgoing gases on their way to the stacks. Free air is taken in through a large Dyblie Air Reversing Valve and preheated in the air regenerator chamber, uniting with the hot gas at the port of the furnace, and giving combustion. It likewise is reversed through the other air regenerator at the time of gas reversal. On the two Open Hearth plants 1.53 miles of gas flues were installed leading from the Producer to the valve, all being lined with hard fire brick. The total installation of Producers and flues required a lining of one million and a quarter fire brick.

Coal is carried up above the Producer charging floor on a trestle track where the cars dump into bins, leading to two crushers. These crusher plants are situated one-third of the length of the installation apart and break the coal to such a size as will pass a 2-inch mesh. Two Bartlett & Snow Conveyors elevate the crushed coal to two overhead storage bins, each holding 600 tons. From these bins it is drawn by four overhead charging cranes of five tons capacity each and fed to the individual Producer hoppers. Each crane is equipped with scales.

A conception of the size of each aggregation which stretches for 1200 ft., or about a quarter of a mile alongside of an Open Hearth plant can be obtained from a few figures of coal consumed and gas generated. Each installation of seventy Producers running at normal capacity will need 800 tons soft coal per 24 hour day or twenty 40 ton carloads, which means that for every running hour of this plant one car of coal is consumed. From this coal close to 4,000,00 cu. ft. of Producer gas is generated every hour, or about 100,000,000 cu. ft. every twenty-four hour day. Average practice shows that it takes about 800 pounds of coal to melt a ton of steel; hence, 2,000 tons of steel can be melted per twenty-four hour day, each ton requiring 50,000 cu. ft. of gas.

The Morgan Construction Company are the sole manufacturers of the Dyblie Reversing Valve. They have equipped both Open Hearth Plants, requiring three valves per furnace, or eighty-four valves to the pail and billet mills' soaking pits, giving a total contract of 132 valves.

There are three types of gas valve—known as the Mushroom, the Butterfly and the Rotating. The Mushroom type is the crudest, and necessitates eight valves per furnace and an

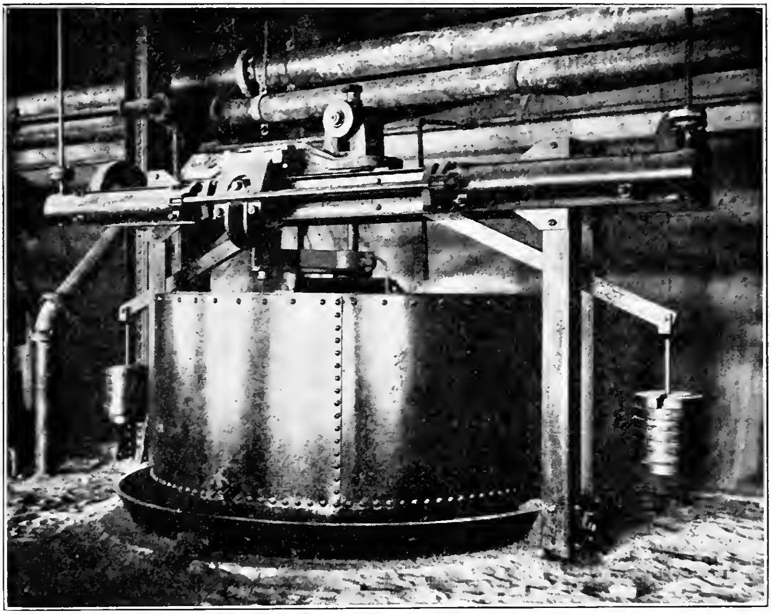

FIG 8. DYBLIE WATER SEALED, WATER COOLED REVERSING VALVE

elaborate system of flues for reversing. In the heat to which the valves are subjected it is next to impossible to keep the Mushroom in shape to seat itself tightly. The Butterfly type has been long in vogue, water cooled and otherwise, but will never be constructed not to burn out rapidly and to warp badly. The water-sealed and the water-cooled valve seems to meet the situation best. Of this type the Dyblie Valve is obtaining a wide reputation as having the greatest simplicity, reliability and economy with the least depreciation.

The Dyblie Valve is maufactured with three or four ports. It consists of a Base Casting or valve seat, a steel plate cylindrical Shell or Casing, and a Superstructure. The Base Casting is the valve seat through which the gases enter and leave,

being diverted by the compartments of the casing. The casing is water-cooled, and rests on the Base in a waterseal. The Superstructure is built on a basis of two I beams mounted on four vertical angles bolted to the Base Castings in pairs and holds two hydraulic cylinders, which operate the valve by a horizontal piston. This piston accomplishes two purposes at once; it moves a horizontal cam, which raises the valve Casing enough above its seat to permit its turning above the flanges of its seat without breaking the water seal. At the same time it advances a big finger, called the Valve Turner, which engages a turning cam on the vertical shaft of the valve casing and moves the casing either ⅓ or ¼ a revolution according as the valve is three-or four-ported. The cylinders are single stroke and work under a hydraulic pressure of often 500 pounds per sq. in., though 150 pounds will turn the valve when working smoothly. All flues are underground, leading into and away from the valve. It is evident from this design that there can be no warping or improper seating to give leakage of gas; that the mechanism is very simple and compact, giving easy control and little repair. Each furnace requires two three-ported gas air valves.

# THE WESTINGHOUSE NERNST LAMP; ITS DEVELOPMENT, CHARACTERISTICS, AND COMMERCIAL STATUS.

BY A. L. EUSTICE.*

Within a period extending over the last five years, the electrical interests have witnessed great activity in the direction of improved efficiency in station equipments and distribution systems and even more rapid progress has been made in the means of converting electrical energy into light—and the efficiency of application.

While it is probable that many readers are more or less acquainted with the old Nernst lamp, not only in its general construction but also in the electrical characteristics of its elements and the history of its development, still it may be well to touch briefly upon these points that comparisons with the later product may be more forcibly brought to your attention.

In the development of high efficiency lamps, the appearance of the A. C. Nernst lamp in America in 1901 marked the first step in high efficiency in a commercial lamp and further gave that high efficiency in incandescent units of larger size than was the practice at the time, thereby filling the existing gap between the carbon incandescent and the arc. The value of high efficiency in medium and large units was immediately recognized and within a short time, the demand on vacuum incandescent lamps resulted in the marketing of the Meridian lamp, a lamp showing little gain in efficiency but a decided step forward in size and distribution of light.

A little later the metallized filament (GEM) lamp appeared with an increased efficiency over the Meridian and in units of still larger size. But scarcely had the lamp consumers been acquainted with this new lamp until it was announced that another, the Tantalum was ready for the market. The Tantalum showed a decided increase in efficiency but the size did not fulfill the requirements of the users.

Although the three vacuum lamps above mentioned were all heralded as a great success, the lamp consumers were not thoroughly familiar with their performance when they were all superseded by the Tungsten lamp, which has not yet been marketed for a sufficient length of time to enable one to judge of its performance and commercial value. Extraordinary activities in the development of the Nernst glower have placed the Westinghouse lamp at the head of the list of high efficiency incandescent units, which position it unquestionably occupies at the present time.

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Notwithstanding the rapid appearance of the various vacuum high efficiency lamps, the demand for A. C. Nernst lamps steadily increased and in 1907 the Direct Current lamp was placed on the market; not, however, until laboratory investigation and one commercial installation of 4,500 units operating for nearly two years showed that the D. C. Lamps could be manufactured for successful operation. About a year ago, a lamp showing a gain in efficiency of 37% was available for both alternating and direct current circuits; and at present a still higher efficiency, in the Westinghouse Nernst lamp, so named in order to distinguish it from the old and now obsolete designs, is the standard product.

The Westinghouse Nernst embodies over the Nernst lamps of the old design, an increased efficiency, a greater variety of sizes, the application of the lamp to 110 volt service, a simplified maintenance or renewal system, and improvements in mechanical construction; and also maintains the additional characteristic features of the old lamps: namely, low maintenance cost, natural downward distribution of light, absence of flicker, pleasing quality of light, unity power factor, maximum flexibility, and adaptability to artistic fixture design.

The development of the Nernst lamp from its original crude, unreliable state, when first introduced in America by Mr. Westinghouse, into the efficient, practical, neat appearing, commercial lamp of the present day, involved the solution of serious difficulties which were encountered at each step forward. The skill of the scientist and chemist was taxed in the problem of separating the rare elements from the earth and combining them in such proportions as to give the desired performance. The electrical engineer solved the complex electrical problems presented by solid electrolytes and high temperature conditions in the circuits, and arranged the elements so as to give high efficiency; while the mechanical engineer and designer were taxed to produce a design which would fulfill commercial requirements, and at the same time lend itself to any architectural treatment.

The elements of the Nernst Lamp in the order of their importance are the glower, ballast, heater, cutout and the body. In the consideration of the performance of these elements it is not my purpose to describe the details of exhaustive experimental research but rather to outline a few of the more important results of our work.

The Glower, or the light emitting element, is the distinguishing feature of the lamp. It is made by pressing through a die, a dough composed of the oxides of rare earths mixed with a suitable binding material, cutting the porcelain-

like string thus made into proper lengths, drying, roasting, and finally attaching the lead wires. It is about 1 inch long 1-32 inch in diameter (the exact size depending upon voltage and current) and is about as strong as a piece of porcelain of like demensions, and in short sections, is rather difficult to break.

At ordinary temperatures, the glower is a non-conductor but becomes a good conductor when heated to about 700 deg. Cent. It is also a solid electrolyte whose action is apparently improved by the presence of oxygen. Since it is an oxide, and hence incapable of further oxidation, it is capable of being operated in the atmosphere at a very high temperature. However, as temperature has a direct bearing on efficiency, it is desirable to operate the glower within a globe, where the heat liberated is more or less confined.

Electrolytic action, as might be supposed, has no effect when the Glower is operated on alternating current; while in a glower operating on direct current, its effect is noticeable, but is compensated for by employing a different form of treminal. In this one feature, the glower, will be found only difference in the A. C. and D. C. lamp.

The characteristic of a glower, with reference to voltage and current when operating in the open air, is remarkable; and has given rise to the necessity of a steadying resistance. As the current in the glower is increased, the voltage across the terminals rises, at first rapidly, and then more and more slowly to maximum; beyond which it again drops off with increasing rapidity as the current, and the resulting temperature through the glower, continues to increase. Beyond the point of maximum voltage, the decrease in resistance of the glower is so rapid as to make the current difficult to control. In fact, without a steadying resistance, such a conductor would rapidly develop a short circuit and "flash out."

In studying the characteristics of the glower and seeking for methods of operation under the best possible conditions, we naturally exploited the field in various gases, including a vacuum; and although the experiments in this direction have been more or less exhaustive from a scientific standpoint, the the results have been negative so far as practical results are concerned, and have demonstrated that there is nothing to be gained in that direction.

The characteristic curve in vacuum and air shows a wide variation in the glower's performance. Aside from the fact that the vacuum shifts the point of normal watt efficiency to a much lower voltage and higher current density, it also produces

a characteristic which has no crest, so that all points lie on one side, giving a decreasing difference of potential for an increasing current. Such a condition as this involves the use of a relatively large steadying resistance and renders the commercial operation of the glower inefficient. Nitrogen and hydrogen curves, as in the case of the vacuum also show that the glower, when operated in these gases, requires a large steadying resistance and thereby lowers the available efficiency. It is, however, very interesting to note that the performance of the glower in the air and oxygen is very much the same, and further, that the absence of either oxygen or air produces a sluggish action, i. e., it responds but slowly to changes in line voltage.

The advantage to be gained by the use of a steadying resistance which would enable the glower to be operated efficiently at a point on or beyond the crest in the characteristic air curve, is at once apparent. In order to operate under all conditions of commercial service and with minimum loss under normal conditions, the steadying resistance should have a very marked positive temperature correction, and at the same time its corrective power must be immediately available. As an illustration: if the glower were operated on or beyond the crest of the characteristic, the current could obviously be controlled by a sufficiently large steadying resistance having no temperature correction, but such resistance would very materially decrease the net efficiency of the glower. On the other hand, if the resistance has a high temperature coefficient, the necessary steadying resistance under normal conditions may be very much less than when no temperature correction is present; in which case, should there be an increase in voltage above normal, the corrective power of the steadying resistance would be brought into service to check any abnormal flow of current through the glower, or in other words, to take up the additional voltage. As already stated, however, the temperature correction should be immediately available, in order to prevent the glower from " shooting over " when lighting above normal pressure; that is, take more current the moment the voltage is applied than it would few moments later, after the temperature correction of the steadying resistance had asserted itself. This would also be the case in any sudden increase in the voltage applied to the glower, unless the corrective power of the steadying resistance were immediately available to check the rush of current.

This resistance, commercially termed the " Ballast," is a fine iron wire mounted in a glass tube filled with an inert gas, Its remarkable protective power can readily be seen when for

a rise of 10% in current, its resistance increases 150%, so that a glower thus protected becomes at once operative throughout a very wide range.

As already stated, the Glower is a non-conductor when heated to a certain temperature. For service, therefore, it is necessary to employ some means to bring the glower up to a conducting temperature. This is accomplished by means of a small electric heater placed immediately above the glower, which not only effectively heats the glower in a minimum time but also serves as a light reflecting surface.

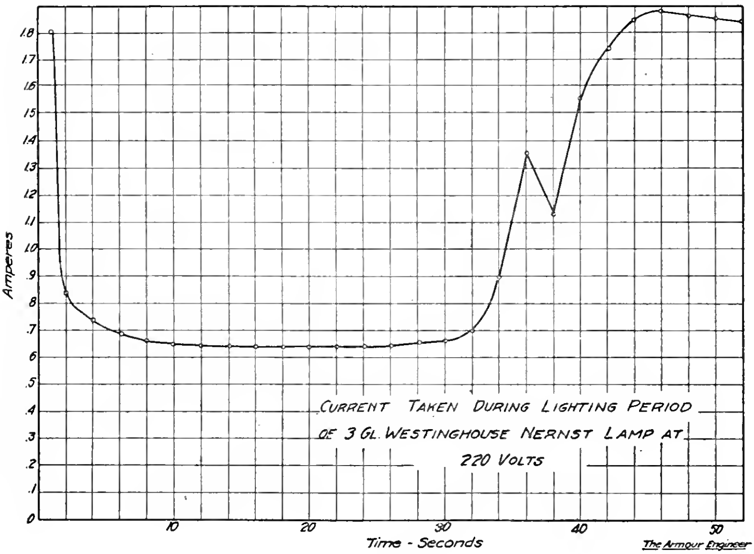



Fig. 1.

The current in the heater is controlled by an automatic magnetic gravity cutout, whose armature is part of the heater circuit and whose winding is part of the glower circuit. Thus, upon closing the lamp circuit, the heater circuit being closed by the action of gravity, takes current and is interrupted as soon as sufficient current is taken by the glower to lift the armature.

Note, graphically (Fig. 1), this action in the lamp from the moment the current is turned on until the glowers in a three-glower lamp are all in operation. During the first 30 seconds, the current taken is that of the heater only. The glowers then start to take current. At the end of 36 seconds the cutout acts, throwing the heater out of service. Two sec-

onds later the second glower has taken normal current and the third is rapidly increasing from the heat of the other two. The glower current reaches its maximum after about 50 seconds, and a very slight drop is noticed at the end of several minutes after the lamp body and ballasts have reached their normal operating temperature conditions.

While the foregoing remarks relative to the elements of the Nernst lamp apply in particular to the older types of lamp; the same principles, improved in many respects, also apply to the new Westinghouse Nernst type.

In the new lamp, the glower has been improved mechanically and electrically. The addition of certain radio-active materials in the glower itself results in a more uniform candle power performance. A new terminal design materially reduces the terminal losses due to the Peltier effect, and therefore provides a longer lighting length between the terminals for the same voltage; and the use of a hollow glower instead of a solid rod, as was the former practice, provides a greater light-emitting surface for the same current. The combination of these features results not only in a higher efficiency, but also is a better individual life performance; an advance which is of much greater importance than any corresponding increase in average life.

While I wish to impress the fact that the average life performance of the glower has, in the past, exceeded the manufacturer's guarantee; yet comparatively early failure of the glower was not infrequently met. The successful development of the glower having a long individual life gives the Westinghouse Nernst lamp a distinctive feature found in no other illuminant.

The normal limits for operation of standard glowers are from 200 to 260 volts on 220-volt class, and 100 to 130 volts on 110-volt service. Of the various units, the Westinghouse Nernst system as now marketed consists of six units for use on both A. C. and D. C. of 220-volt, and three units for both A. C. and D. C. of the 100-volt class; for indoor and outdoor service, which are popularly termed 66, 88, 110, 132-watt single glower, 2-glower, 3-glower and 4-glower lamps. Within a short time, a 5-glower lamp will be added, the largest incandescent unit ever offered for practical illumination. The 110-volt lamps at the present time are offered only in three sizes of single glower units, 66, 110, and 132 watts.

The Westinghouse Nernst may be classified under three heads: multiple glower units, single glower units, and chandelier units.

The mechanical construction of the multiple glower lamp presents a design which combines simplicity and compactness. (Fig. 2.) The unsightly exposed terminals and supporting hook, commonly used, have been replaced either by a fixture nipple by a small hook through which the service wires enter the top of the lamp housing and terminate in two binding posts in the body of the lamp.

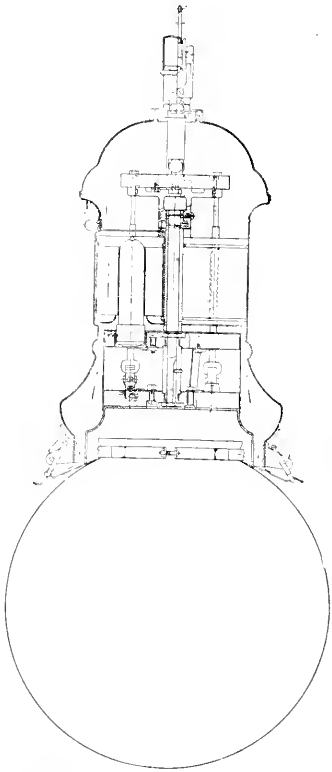


FIG. 2. SECTIONAL VIEW OF MULTIPLE-GLOWER WESTINGHOUSE NERNST LAMP.

Immediately below the terminal porcelain is the section of the lamp in which the ballasts and ballast coolers are placed. The ballast coolers are built up of flexible phosphor bronze and are securely fixed to the upper part of the lamp housing in such a way that a firm contact is made on the surface of the ballast and a metallic contact is secured with the housing presenting a greater radiating surface.

The housing is so constructed that a movement of the locking lever will permit its separation to a convenient distance, exposing the ballasts to view, thus making replacement an easy matter. In contrast to this simple method, it will be remembered that the ballasts in the old lamp were arranged in a semi-circle about the cutout, and in order to gain access to them it was necessary to remove the suspension hook and the top of the lamp housing.

Below the ballast porcelain is the sleeve porcelain on whose upper side is the cutout, and into which the holder is inserted from below. The cutout armature (being the only movable element in the operating system) is enclosed in a dust-proof compartment, so that the lamp will operate successfully without regard to climatic conditions.

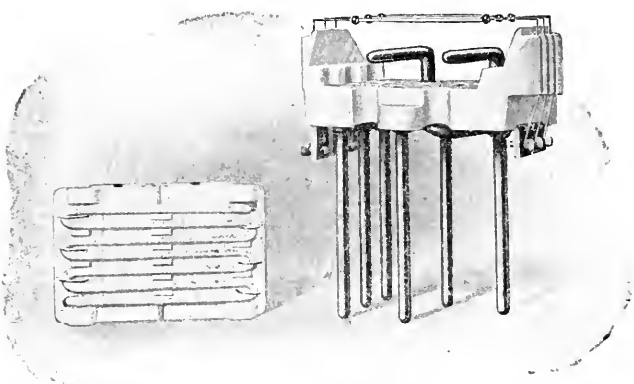


FIG. 3. WAFER HEATER AND HOLDER.

The holder of the Westinghouse multiple units presents a radical change in design. The old two-piece porcelain is replaced by a one-piece holder base, to which is attached the characteristic terminal prongs. Two prongs are brought through the holder base and are secured in such a manner that they lie in a plane parallel to the glowers and at right angles to them. The use of two or more heater tubes is superseded by a "Wafer Heater" (Fig. 3), a heater consisting of a small platinum-wound and refractory cement coated rod, bent so that several sections lie parallel to the glowers and securely mounted on a flat porcelain. The wafer slides on the heater prongs when inserted in the holder; the heater terminals being in the form of a sleeve contact. Hence it will be noted that heaters can readily be changed without tools and without disturbing any other member of the lamp.

In view of the fact that the heaters and glowers are mounted on a removable piece or holder, the design being such that the heater is immediately above the glowers, the following advantages are resultant: Stagnation of the heat liberated from the heater, thereby lighting the glowers in minimum time; no shadow, since no element is below the glower to interfere with the flux of light emanating in the useful direction; and stagnation of heat from the glowers whereby the latter are operated in their own heat, and therefore at a higher efficiency than would be possible with any other arrangement.

An improved method of supporting the globe is employed so that the glassware can be removed instantly, and at the same time is locked to the lamp body, thus minimizing both labor in cleaning and breakage due to careless handling.

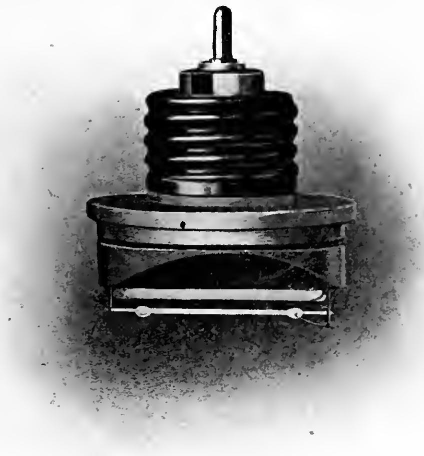


FIG. 4. WESTINGHOUSE NERNST SCREW BURNER WITH GLOBE REMOVED

The various sizes of single glower units are of the Edison Base type (Fig. 4), and present a similar appearance to the now popular 110-watt unit, although the construction is a unique departure from former practice. The cutout is located within the Edison base; immediately under which is the ballast secured by means of a bayonet catch. Three prongs lead to the base porcelain, the lower side of which forms the Nernst receptacle.

The holder (Fig. 5) consists of a glower and wafer heater permanently connected on a small porcelain provided with a standard screw base, with an additional contact pin in the center. By an assortment of diameters and lengths of contact pins, it is impossible to insert any other than the proper holder

in the lamp, thereby insuring the consumer against troubles incident to the use of lamps of various sizes and class of voltage.

This form of renewal is popularly termed the "Screw Burner," and should supply the demand for a high efficiency incandescent lamp, so rugged in its design that the lamp can be maintained by anyone. The burner is furnished complete with glassware when small balls are desired and without glassware when the standard size of ball is used on the lamp.

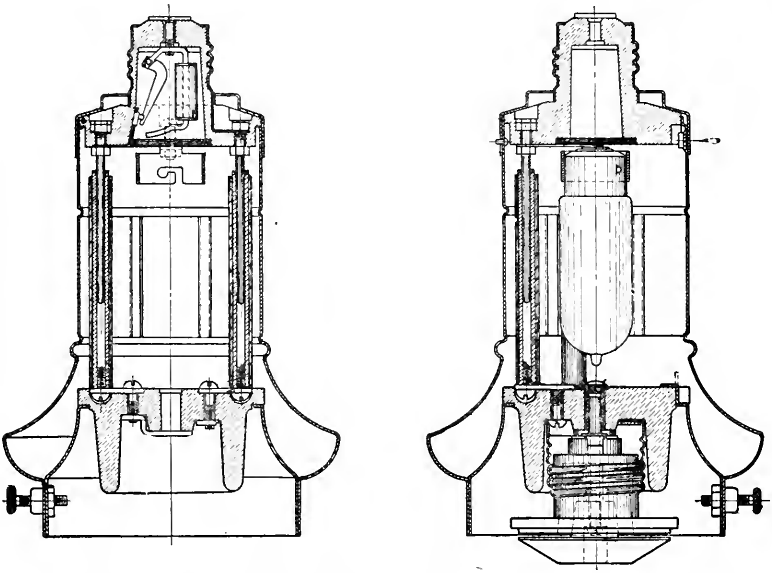


FIG. 5. SECTIONAL VIEWS OF SINGLE-GLOWER WESTINGHOUSE NERNST LAMP.

Owing to the extremely rugged construction of the screw burner and the method of packing each burner in a small metal box, it is possible to secure renewals by return mail, since the severe treatment to which mail packages are subjected cannot injure the burners while in transit. Large shipments are recommended by freight regardless of the distance, for there is no feature about the lamp that requires more care in handling than is given ordinary freight.

Having outlined the electrical and physical properties of the various types of Westinghouse Nernst lamps, the subject of candle power performance will be in order. The immediate corrective power of the ballast when the lamp is subjected to variations in voltage is apparent from the curve shown (Fig. 6). It will be noted that for a given voltage below normal,

the glower characteristic is predominant, as shown by the rapid increase in curvature as normal voltage is approached; at and above normal, the ballast modifies the curve and its effect is noted in comparison with curves No. 2 of the Tungsten lamp, and No. 3 of the carbon filament lamp. The curves given clearly indicate that the performance of the ballast permits only of slight variation in candle power for variation in line voltage in the Westinghouse Nernst, and further, that the

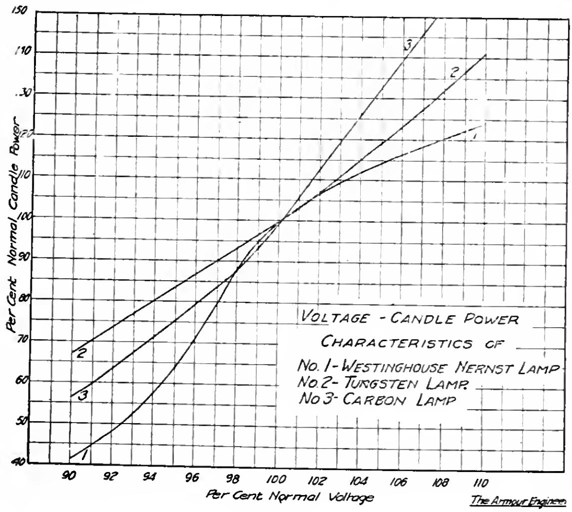



FIG. 6.

Westinghouse Nernst gives the minimum variation of all illuminants.

Another interesting comparison is given (Fig. 7) between the Westinghouse Nernst and the D. C. arc for so-called constant impressed voltage. In the Nernst the candle power is constant, while in the arc the candle power is rapidly changing due to slight adjustments of the length of the arc as well as the inherent changes produced by the slight change in line voltage, since the corrective power of the arc's resistance is not immediately available.

The natural downward distribution of light about the Westinghouse Nernst Lamp is one of its most valuable assets, and herein lies one reason for the high efficiency of installation. I open what is to be but a brief review of distribution curves by this statement, that I may in the strongest possible way give emphasis to the remarkable fact that in no other incan-

descent lamp is such a natural condition to be found. It is to be noted that advocates of the vacuum incandescent units recommend their use for lighting interiors only in connection with reflecting devices, so that a consideration of those units should be based on a combination of the lamp with its reflecting device.

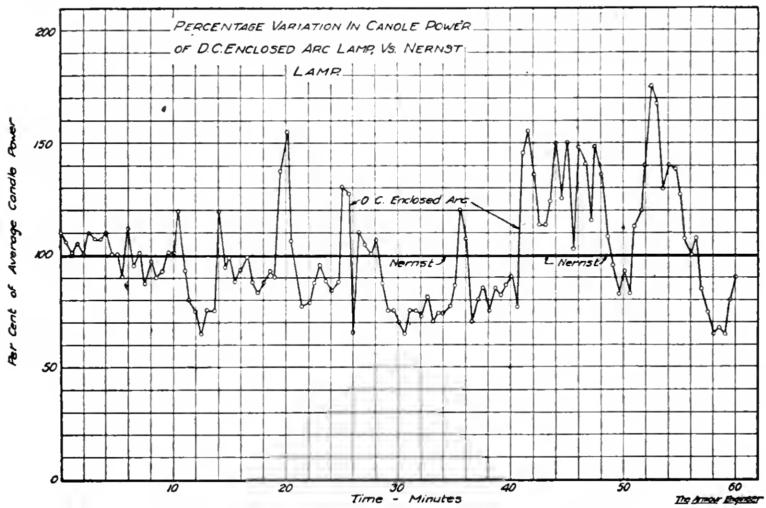



FIG. 7.

The distribution of the vacuum lamp can be more or less corrected by reflectors; but the nearer the desired distribution we have, naturally the less light will be reflected, and consequently, the less will be the total loss in the process of reflection.

The natural downward distribution of light from the Westinghouse Nernst is shown in the following curves (Figs. 8 and 9), which are self-explanatory. In order to make a rapid comparison of the mean hemispherical values of each unit, as represented by curves, the table of efficiencies is given below.

The peculiar softness and low intrinsic brilliancy obtained by the use of light alabaster glassware, despite the fact of a concentrated source and a downward distribution, has a pleasing effect on the eye. Exhaustive tests on the performance of glassware indicate that light alabaster glass is but slightly diffusing, and therefore, does not materially change the character of the distribution curve. The loss of light due to ab-

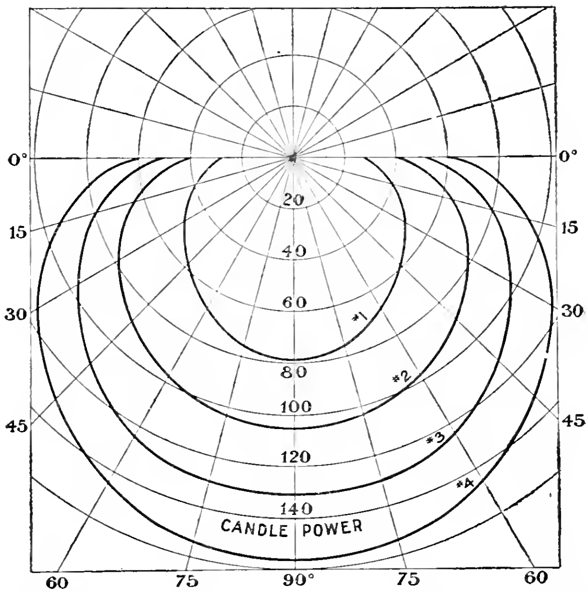



FIG. 8. DISTRIBUTION OF LIGHT FROM SINGLE-GLOWER WESTINGHOUSE NERNST LAMPS

1— 66-watt lamp, using 4-inch clear globe
2— 88 " " " 4 " " "
4—110 " " " 5 " " "
5—132 " " " 6 " " "

TABLE I.

MEAN HEMISPHERICAL EFFICIENCIES WESTINGHOUSE NERNST LAMP.

| Lamp | Glassware | Maximum Candle Power | Mean Hemisph. Candle Power | Mean Hemisph. Efficiency |
|---|---|---|---|---|
| 66 watt | 4″ | 74 | 50 | 1.38 |
| 88 " | 4″ | 105 | 77 | 1.2 |
| 110 " | 5″ | 131 | 96.4 | 1.2 |
| 132 " | 6″ | 156 | 114 | 1.2 |
| 2-Glower | 8″ | 345 | 231 | 1.2 |
| 3 " | 8″ | 258 | 359 | 1.15 |
| 4 " | 8″ | 745 | 504 | 1.09 |

sorption is approximately 15% over clear glass, so that the performance curves for alabaster glassware can be obtained by applying the correction factor. Naturally, any data such as the above, presented on the behavior of commercial globes toward light, should be considered indicative rather than conclusive.

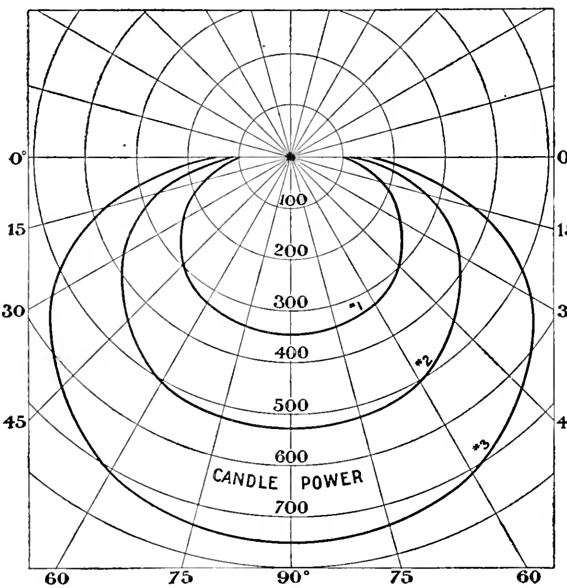



FIG. 9. DISTRIBUTION OF LIGHT FROM MULTIPLE-GLOWER WESTINGHOUSE NERNST LAMPS.

| | | | | | | |
|---|---|---|---|---|---|---|
| 1—2-glower | lamp, | using | 8-inch | clear | globe. | |
| 2—3 " | " | " | 8 " | " | " | |
| 3—4 " | " | " | 9 " | " | " | |

Comparative figures with various modern illuminants will be seen by a glance at the table (Table II) of mean hemis. efficiencies: data on Tungsten lamps taken from published data of the N. E. L. A.; that of arc lamps from Prof. Mathews' report on Arc Lamps; and figures on Nernst lamps from the Company's laboratories.

TABLE II.

| | Eff. W. per c. p. |
|---|---|
| 4-Glower West. Nernst Dome Shade and Heater Case.... | 1.07 |
| 4-Glower West. Nernst 9 in. Clear Globe ............... | 1.12 |
| Tungstolier with Clear Prismatic Reflectors............ | 1.22 |
| 4-Glower Westinghouse Nernst 9 in. Alabaster Ball...... | 1.28 |
| D. C. Arc-Shade ......................................... | 1.37 |
| Tungstolier with Enameled Prismatic Reflectors......... | 1.45 |
| Old 6-Glower Nernst Lamp 8 in. Alabaster Ball......... | 1.64 |
| A. C. Enclosed Arc-Shade............................ | 1.75 |

Next in order of importance is the life of the unit. A summary of the life of the various elements is given in the following table (Table III). These figures are the basis of the standard guarantee given on any installation of over 100 units for the average life performance when operated on a circuit whose regulation is within 5% above or below the normal point of operation. Statistics, however, compiled from a great number of old commercial installations indicate that the average life of the various elements is far greater than the figures herewith given.

TABLE III.

| PART | HOURS' LIFE | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | DIRECT CURRENT | | ALTERNATING CURRENT | | | | | |
| | | | 25 Cycle | | 60 Cycle | | 133 Cycle | |
| | 110 V. | 220 V. | 110 V. | 220 V. | 110 V. | 220 V. | 110 V. | 220 V. |
| Glower ..... | | 600 | | 400 | | 800 | | 800 |
| Heater ...... | | 3000 | 3000 | 3000 | 3000 | 3000 | 3000 | 3000 |
| Ballast ....... | 15000 | 15000 | 15000 | 15000 | 15000 | 15000 | 15000 | 15000 |
| Screw Burner.. | 600 | 600 | 400 | 400 | 800 | 800 | 800 | 800 |

The color of the light given by the Nernst lamp is another of its many distinctive features. It is a so-called white light, yet it has a soft and rich warmth of color which illuminating authorities recognize to be the easiest upon the eye, the most pleasing to the senses and the best for general lighting of all places. In short, the quality of Nernst light meets the popular demand so well expressed by one of the leading merchants of the country when he said: "What we want is a soft, warm, inviting light—not a cold, cheerless, repelling light."

By reason of the natural downward distribution of light, the wide range of sizes, and the simple system of renewal, the

lamp offers great latitude in artistic fixture design, so that the range of artistic possibilities is within the scope of the most critical eye. The units may be used with equal satisfaction as a unit source, in clusters, in ceiling bowls, or in fixtures of elaborate design. The artistic ceiling bowl unit by reason of the adaptability of a high intensity in a limited space, can be used for efficient commercial lighting; a type of unit not practicable with any other system. In this unit the elements are built radially about the base porcelain in contrast to the vertical position used in the standard lamps. With the Westinghouse Nernst system, absolute uniformity in quality of illumination can be obtained throughout any installation, no matter how diverse the requirements.

A departure from former fixture practice is present in a distinctive design of Nernst chandelier units (Fig. 10). Heretofore, the complete single glower lamp was used in a pendant position in ordinary fixtures, but in many cases the appearance of such a combination did not harmonize with the architectural features. The new chandeliers are constructed with the ballasts and cutouts in the body, so that the Nernst receptacle forms the socket into which the screw burner only is placed. In this design, the lamps may be operated in any position, and a lamp presenting to the eye only a 3 in. ball, will lend itself to artistic effects without limit and still provide efficient illumination. These chandeliers are made of both spun and cast bronze for use with any size of single glower lamps, and may be obtained in straight electric or combination gas and electric types.

Single glower units are especially desirable for window lighting. Either the direct or indirect method can be used with equal satisfaction, showing the display in a light whose color does not distort the color values of the display. For direct lighting, a special dome reflector may sometimes be advisable. In the indirect system, a Nernst special window reflector is offered which conceals the lamp so that no direct light will meet the eye of the observer, and at the same time distribute all the light within the window, rather than on the sidewalk and street.

Unlike the incandescent lamp, the frame and connections of the Westinghouse Nernst lamp from a permanent structure having an indefinite life, but its light-giving elements have from time to time to be renewed. Of these the ballast has a life so long, as before mentioned, that it plays little part in the maintenance system. Likewise, the heater has a very considerable life, and will require only occasional attention in ordinary use. The glower, however, like the vacuum lamp,

has a practically definite term of use; and is the item of greatest importance in the maintenance system. It is now generally recognized that any lighting system, be it incandescent, arc or Nernst, will give the best results when provided with a regular inspection and systematic maintenance.

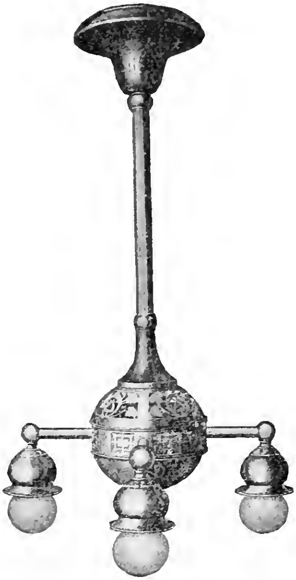


FIG. 10. WESTINGHOUSE NERNST CHANDELIER UNIT.

In view of the general similarity in the construction of the arc and the multiple glower Westinghouse Nernst, it is self-evident that the maintenance is much the same. In the arc system the lamps are periodically inspected, globes and shades cleaned, carbons renewed, and occasional faults in the internal mechanism or a burned out coil repaired. In the Nernst system, the requirements are cleaning glassware, and replacing burned out holders. The extra labor which is necessary for the subsequent repairs of holders in the Nernst system is about counterbalanced by the extra time required in the arc system for more frequent inspection tours.

A system usually adopted by lighting companies is the organization of a Maintenance Bureau which maintains all lamps on the circuits; visiting all installations periodically,

and changing holders when necessary. The total cost of maintenance under these conditions will be comparatively low, provided the work is executed in a systematic manner. In case the lamps are not installed on the free renewal basis, this maintenance is then supplied for a fixed sum per glower per month, or for an additional charge per K. W. hour for current. The exact sum depends upon the class and length of service but averages 10c per glower on the former basis, and from 5 to 7 mills per K. W. H. for the latter. It is obvious that location and cost of labor have a rather important bearing on the cost of any specific installation.

When screw burner lamps are used, the maintenance problem becomes that of the old system of ordinary incandescent renewal. Where free renewals are not the custom, the user returns the burned out burner, for which he receives a rebate towards a new one. With this system, the Company is prepared to supply all the necessary burners for a specified sum per year, based upon the length of burning hours. The advantage of this guaranteed renewal or maintenance cost is at once evident as compared with the unknown quantity representing renewal costs in commercial installations of vacuum high efficiency lamps.

It is at once apparent that a system which does not require reflecting devices is the simplest and most economical to maintain because of less glassware to break and the absence of all labor involved in the constant cleaning that reflectors require in order to keep reflector lamps up to normal efficiency.

The efficiency of installation can best be studied by a review of a few typical existing commercial installations, for the experience of those who have had commercial installations is well worth considering when judging the value of a lighting system.

Such installations as those in the administration buildings of Sears, Roebuck & Co., Deering Harvester Works, Armour & Co., Swift & Company; Chicago, Milwaukee & St. Paul R. R., and Marshall Field & Co., all in Chicago, produce proof of the superiority of the Nernst lamp for general illumination.

A review of an investigation of an installation in Pittsburg will no doubt be of great interest and value. A large department store was the first to install Nernst lamps when they first appeared on the market; and a few months ago, were again among the first to install Westinghouse Nernst lamps in place of the old equipment after having made tests on various modern illuminants.

Illumination tests showed the following results:

1. Old 6-glower Nernst lamps; Old Alabaster Glassware (of density used in the year 1902); Old Holders, under normal maintenance conditions. The mean illumination was found to be 3.95-foot candles for 1.88 watts per square foot.

2. Same conditions except new Westinghouse Nernst type of 9 in. alabaster glassware substituted for old glassware; mean illumination 4.43-foot candles, showing an increase of 12% due to glassware alone.

3. Old type 6-glower Nernst type equipped with new glowers and same new glassware. The illumination was then raised to 4.88 f. c., which indicates a candle power depreciation of approximately 9.4%.

4. An equipment of three-glower (New Westinghouse) Nernst lamps, using the same glassware at each outlet, reduced the wattage to 1.41 watts per sq. ft., and increased the illumination to 5.12 f. c. This indicates that the net efficiency of the installation was raised approximately 28%; and the maintenance cost, even under these conditions, was materially decreased.

In conclusion, I wish to advise against the use of misleading figures on Westinghouse Nernst lamps which may appear in the technical press due to the unfamiliarity of the authors of the same with the performance of the lamp; and respectfully call your attention to articles by the writer, which appear from time to time, giving results of exhaustive tests carried on under the direction of the Company. These show, not what the lamps theoretically should do—but what the performance of the Westinghouse Nernst lamp actually is when operated under existing conditions found in commercial installations.

# A HEAT VALUE CALCULATOR.

## A Device for Calculating the Heat Value of Blast Furnace Gas from Its Chemical Analysis.

BY CHARLES C. SAMPSON.*

In the daily record of the performance and in the reports of tests of gas engines frequent calculation must be made to determine the heat value of the gas used. This great number of determinations takes much time, and the calculator described is to reduce this time to the lowest possible amount.

The combustible portion of the blast furnace gas is made up of carbon mon-oxide, hydrogen and methane in amounts varying according to the operation of the furnace and its charge, and atmospheric conditions; the extremes being about as follows:

For C O—22% to 35%
H — 1% to 6%
$CH_4$—0. 1% to 1.0%

The heat value in B. T. U. per cu. ft. at 62° F. and 29.5 in. Mercury for the three gases is, according to H. B. McFarland's tables,

C O —324.45
H —274.78
$CH_4$—915.08

and the heat value of one cu. ft. of blast furnace gas would be

$$\frac{324.45 \times \%\ CO + 274.78 \times \%\ H + 915.08 \times \%\ CH_4}{100}$$

where the analysis is given in % of volume.

Thus the heat value of a gas having the following analysis:

$CO_2$—10.4%
C O —28.3%
H — 2.6%
$CH_4$— .2%
N —58.5%

would be

28.3 X 324.45=91.819
.026 X 274.78= 7.144
.002 X 915.08= 1.830

100.793 B. T. U. per cu. ft. at 62° F.=29.5 in. Hg.

*Class 1904. Engineer Construction Dept, Indiana Steel Co., Gary, Ind.

The calculator is in three parts—first a circular scale of B. T. U. arranged to cover the range of probable heat values for the gas to be analyzed, which for blast furnace gas may be from 70 to 130 B. T. U. This gives a range of 130—70=60 B. T. U., and for a reason shown later, this scale was made to cover B. T. U. from about 65 to 135.

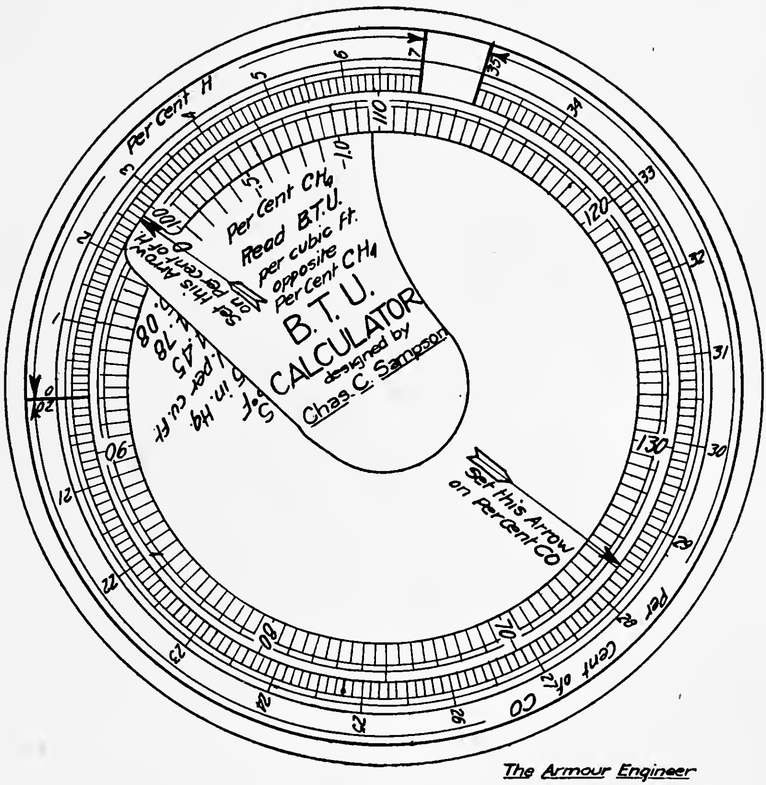
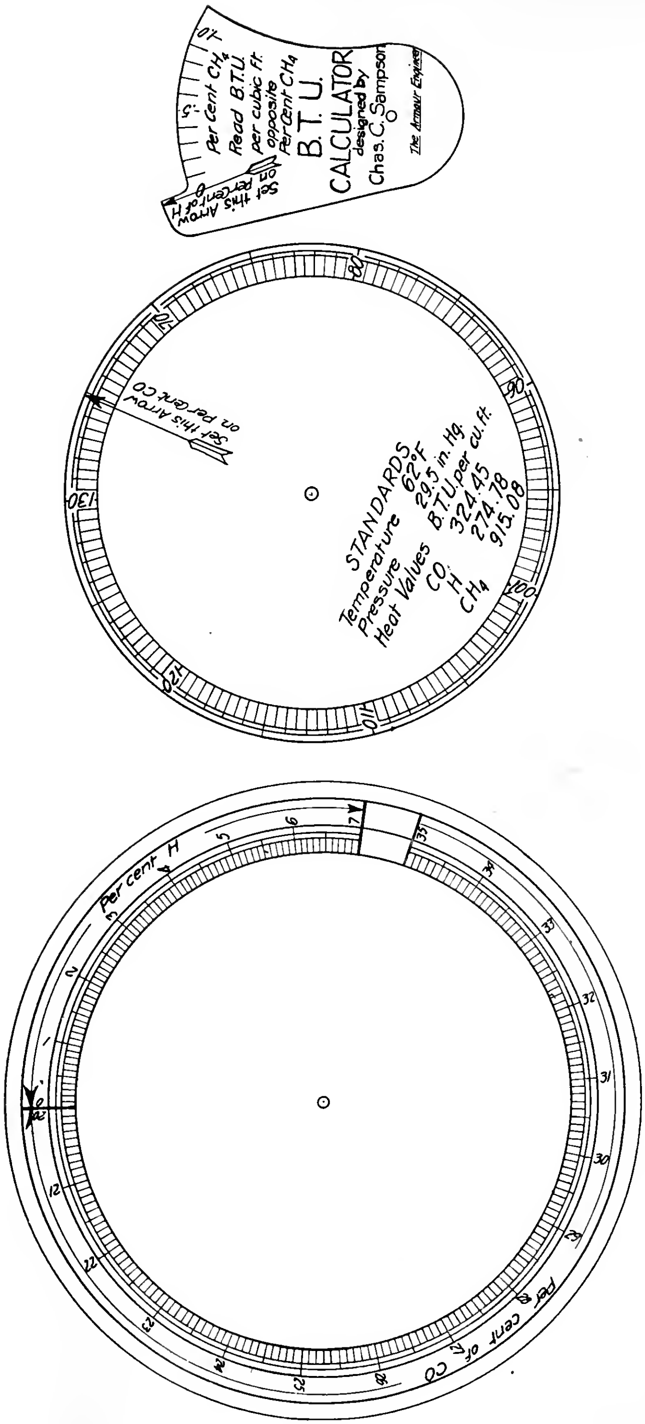



FIG. 1. CALCULATOR SET FOR EXAMPLE IN TEXT.

The second part is a circular scale of "% of C O" and "% of H" so graduated that each "% of C O" extends over 3.2445 divisions on the B. T. U. scale while each "% of H" extends over 2.7478 of the B. T. U. divisions.

The "% of C O" range is from 20 to 35 and for "% of H" from 0 to 7. The total B. T. U. represented by these two scales making necessary the extension of the B. T. U. scale to cover 70 B. T. U. rather than 60 B. T. U.



Per Cent $CH_4$
Read B.T.U. per cubic ft. opposite Per Cent $CH_4$
B.T.U. CALCULATOR
designed by Chas. C. Sampson
The Armour Engineer
Set this Arrow on Per Cent of H
Set this Arrow on Per Cent CO
STANDARDS
Temperature 62°F
Pressure 29.5 in. Hg.
Heat Values B.T.U. per cu. ft.
CO 324.45
H 274.78
$CH_4$ 915.08
Per cent H
Per cent of CO


FIG. 2.

The third part is a scale of "% of C $H_4$" whose range is from 0% to 1.0%. The length of each division is determined by the length of the B. T. U. divisions on the first part.

The position of the arrow on the B. T. U. scale is determined by the fact that 20% C O gives a heat value of 64.89 B. T. U.

The illustration (Fig. 1) shows the instrument set for the gas calculated above. The arrow on the first part is set opposite the % of C O (28.3%). The arrow on the third part being at the % H (2.6%) and the heat value (100.8 B. T. U. is read opposite the % C $H_4$ (0.2%).

This calculator is of use only for blast furnace gas although, of course, one with suitable scale ranges could be made for any other gas such as producer gas and coke oven gas.

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[Ed. Note.—In order that one of these calculators may be obtained by readers, there are included (Fig. 2) illustrations of the separate parts, which may be pasted on card board, cut out, and assembled.

## ELECTRONS.

BY G. E. MARSH, JR.*

During the last dozen years a new and interesting scientific theory of the greatest importance has been gradually developed until at the present time, even though it is far from being complete, it stands as the grandest achievement that the world has ever seen in the way of a far reaching explanation for physical phenomena. From the earliest days, electrical science investigators and savants have perseveringly speculated regarding the causes and diligently wrought hypotheses connecting the many and diverse phenomena that were discovered in uninterrupted succession and which have constituted the rapid advance in electrical knowledge. The distinct theories that have been proposed, exploited, tested, accepted or found deficient, have been numerous and in many instances the ingeniousness of the explanation reflected well upon the mind that conceived it. The Faraday-Maxwell explanation based upon the properties of the ether medium, has long been accepted, almost without question, for forty years. The electro-chemical notions of Hittorf, Clausius, and Kohlrausch have been standard, while in the domain of electro-statics neither the one-fluid theory of Franklin or the two-fluid theory of Symmer has made enough progress to occupy the field in undisputed possession.

In the interval from 1893 to 1897 the epoch-making discoveries of Lenard, Roentgen and J. J. Thomson accelerated the development of a new theory based on a new concept and which had been slowly undergoing crystallization as a result of the wealth of knowledge given to the world by the experiments of Crookes, Hertz, Arrhenius and others. More recently the work of Becquerel and the Curies followed closely, furnishing new material and strength to the theory that was rapidly coming to its own.

The atom of electricity briefly hypothesized by Weker, hinted at by Maxwell, definitely conceived by Johnstone Stoney and later treated mathematically by Lorentz, Larmor and J. J. Thomson found itself fully enthroned at the close of the last century. This atom of electricity, with extraordinary properties, is the concept, the entity, around which the electron theory is rapidly rearing an explanation which in its far reaching embrace, and through its potential possibilities in ultimately elucidating all of the near and distantly related electrical phenomena, bids fair to prove itself one of the greatest human achievements of all time. The most enthusiastic

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*Massachusetts Institute of Technology, 1902. Instructor of Electrical Engineering, Armour Institute of Technology.

supporters of the electron theory believe in its future adequacy, its inherent potents in explaining matter, gravitational attraction and other natural quantities which have persistently baffled the scientific genius of all ages. That the theory will in the near future provide a satisfactory explanation for such phenomena as thermo-electricity, voltaic electricity, light, heat, magnetism, radio-activity, the Zeeman, Faraday, Kerr and other effects, not to mention a great many others, goes without saying, and indeed in certain cases the explanations are already tentatively accepted.

In this article it will be our aim to pay attention only to the electron, the atom of electricity, as anything in the nature of a complete exposition of the electron theory would far exceed our present space.

It is a well recognized fact and one that is in accordance with the accepted electro-magnetic ideas, that a moving electrical charge exhibits all of the properties of an electrical current. For convenience let a charge isolated in space be imagined as describing a rectilinear path; then in common with ordinary electro-static charges, produced by friction between hard rubber rod and wool cloth, there exists a system of lines of force which have their origin at the charge on the surface of the rod and extend radially through the surrounding medium. Actually, they of necessity, must terminate on material objects somewhere, but as long as the latter are far removed, the lines of electro-static force are strictly radial.

In addition to these lines there is a second system consisting of closed curves or rings centered upon the path of the moving charge. These are the lines of magnetic force and surround the path in the same manner that a current-carrying wire is encircled. Accordingly, there can be pictured three distinct directions at any given point in the ether in the region of a moving charge: 1. A direction parallel to the direction of motion. 2. The direction of the electro-static field, determined by the radius passing through the point. 3. The direction of the magnetic curve passing through the point and which is at right angles to the two other lines.

The magnetic lines and the motion are co-existent. The strength of the field at any point varies with the density of the magnetic lines at that point and this in turn depends directly upon the magnitude of the velocity of the particle. If **H** represents the strength of the field at any point, **e** the moving charge with a velocity **v** and where $\theta$ and **r** are the polar coordinates of the point referred to the center of the moving body as origin, then

$$H = \frac{ev}{r^2} \sin\theta$$

At the present time the firmly established facts may hardly warrant the statement that there is no magnetic field other than the one spoken of, and expressed by the equation above, although the denial of the assertion calls for proof from those who would assail the idea. According to Oliver Lodge, one of the foremost exponents of the present theory, and to whom many of the present ideas and figures are due, there is no origin of magnetism other than the above. On this supposition we see that with no velocity there is no magnetic field, neither is there any current, merely an electro-static field. With a constant speed the magnetic field and the electric current are constant.

As a short digression, let it be recalled to mind that whenever a conductor moves in a magnetic field in such a manner that the lines of force are cut, there is an electromotive force produced within each longitudinal element of the conductor. The apparent electromotive force is the algebraic sum of those generated in the several elements for it is the one function of a conductor to perform the summation of the elementary electromotive forces. Even though the moving body be a non-conductor, an insulator, the elementary electromotive forces are still produced but there is the absence of all usual phenomena accompanying the passage of an electric current in a conductor. Production of electromotive force is a question of relative motion, and in the ordinary case of a magnetic field changing as a result of a varying current, it is well known that a second electromotive force makes its appearance and is called the electromotive force of self-induction. Furthermore, the direction of this electromotive force it at right angles to the direction in which the magnetic lines of force are moving and its magnitude is proportional to their rate of motion. The above ideas may now be connected to the previously considered moving charge but with the additional supposition that the velocity is no longer constant, that is, its motion is being accelerated or retarded. In any such case the surrounding and accompanying magnetic field is changing, increasing or diminishing proportionately with the change in velocity. A change in the strength of the field is accompanied, as has been shown, by the co-existence of an electromotive force. In the case of the moving charge just such a phenomenon takes place; the electromotive force originating in the ether, the medium surrounding the body and permeated by the magnetic lines. This electromotive force reacts upon the charge, that is, upon its motion in just the same manner mentioned above when speaking of the electromotive force of self-induction. It, too, is

directed along a line at right angles to the direction of motion of the magnetic lines, that is to say, along the direction of motion of the charge and in a sense always to oppose the change producing it. The whole phenonmenon is but an example of Lenz's law, and in accord with the conservation of energy principle.

Sir Oliver Lodge in speaking of the electromotive force of self-induction has given it the very descriptive name, reaction electromotive force; and it is sometimes convenient to speak of it by that appropriate title.

More important still than the reaction of this new electromotive force upon the moving charge is the radial transmission of energy from the body into space and which is the direct result of the charge undergoing acceleration. The transmission of energy in this manner constitutes the phenomena known by the name of radiation and embraces all kinds of ethereal waves, comprising heat, light, Roentgen rays, Hertzian waves, etc., all of which are propagated with the speed of light. If **a** be the acceleration of the charge **e** moving through a medium of magnetic permeability $\mu$, then the energy radiated each second is given by

$$\frac{2 \mu e^2 a}{3 V}$$

where V is the velocity of light, 186,400 miles per second. This expression is due to Larmor and is of the greatest importance in the electron theory. Incidentally it may be mentioned that whenever the same region is occupied or pervaded by an electric field, that is, by electro-static lines, and by a magnetic field, there is a transfer of energy through that region. This is the statement of general truth known as Poynting's Theorem.

Bearing in mind that a current is the result of a moving charge, the relations may be indicated in the following way. Picture the charge as moving along the axis of abscissas and that its instantaneous location may be indicated by Xe; if **i** designates the current and **t** the time variable, then

$$i = \frac{dXe}{dt}$$

represents the involved relationships. In a similar manner

a variable current is given by di/dt and this is clearly

$$\frac{di}{dt}=\frac{d^2Xe}{dt^2}$$

In the theory of the alternating current the electromotive force of self-induction is equal to

$$E=L\frac{di}{dt}$$

where **L** represents the self-induction. Hence the reaction electromotive force

$$E=L\frac{d^2Xe}{dt^2}$$

which may be compared to the corresponding mechanical equation, force = mass x acceleration or f = ma, or

$$f=m\frac{d^2x}{dt^2}$$

The relations of the quantities in the first equation are identical with those in the second; the former involves the acceleration of a charge, the latter the acceleration of a material mass. The inertia of matter opposes a change in its motion, and in the same way, the electromotive force of self-induction operates against a change in the motion of the charge. The analogous properties of the several quantities may be indicated in the following way:

Mechanical inertia results from mass.

Electrical inertia results from reaction electromotive force.

The acceleration of matter is opposed by its mechanical inertia.

The acceleration of a charge is opposed by its reaction electromotive force.

In both the electrical and mechanical cases, the motion encounters opposition when the velocity is increasing and is assisted when the latter is diminishing. Thus it is seen that a charged body possesses an additional inertia. The value of this new inertia is given by the expression

$$\frac{2\mu e^2}{3r}$$

where **r** is the radius of the small sphere carrying the charge **e**. It is to J. J. Thomson that the deduction of this last expression is due.

The actual value of this electrical inertia or mass which is proportional to the energy of the charge is given by

$$m^1 = \frac{2}{3}\cdot\frac{1}{V}\cdot\frac{e^2}{Kr}$$

where $m^1$, and K are the inertia and a physical constant respectively, and the other quantities have the same significance previously assigned. The energy possessed by a body having a mass of only one milligramme and moving with the velocity of light, 186,400 miles per second, amounts to fifteen million foot tons; an astounding magnitude truly. Now thus it is seen that any quantity of electrical inertia which would be comparable with that of a thousandth of a gramme would represent an immense quantity of energy. If a charge of one coulomb of electricity exists on a sphere of such size as to be at a potential of one volt, then the energy will be 3.6 foot pounds and its inertia will be equivalent to that of one hundred millionth part of a milligramme of matter. If the potential of the charge had been ten million volts, the equivalent quantity of matter would then be one hundredth part of a gramme. Again, if the charged body be taken as an atom of hydrogen whose accepted weight, diameter, and charge are $10^{-25}$ part of a gramme, $10^{-8}$ part of a centimeter and $\frac{1}{2}x10^{-2}$ part of a coulomb respectively, a little calculation will show that energy of the charge moving with the velocity of light would be equivalent to a mass of $10^{-33}$ part of a gramme. From this last statement it is seen that the electrical mass of a charged atom would be insignificant in comparison to its material mass which is of the order of magnitude $10^{-25}$ part of one gramme.

As a final supposition let the same charge be possessed by a particle one hundred thousandth the size of the atom; in this case inertia would be that of $10^{-28}$ part of a gramme, or only about one thousandth that of the mass of the hydrogen atom, a relatively fairly comparable magnitude.

The preceding paragraphs contain nothing that is not recognized as accepted facts in the theory of electrical phenomena. The various calculations and numerical results are true independently of the Electron Theory, and have come directly from well established relations. The foregoing introduction furnishes an easy approach to the subject proper, and this we will proceed to outline in an elementary manner. Without going into detail, it may be mentioned that the existence of the electron was conjectured by Maxwell, Crookes, Lodge, and others; and in many cases years before its actuality forced itself into the ideas of men with a persistence that would not be ignored.

Picture a small spherical volume 1-$10^{13}$ part of a centimeter in diameter, and that it contains or possesses a negative charge of electricity, whatever that may be in its absolute constitution, which gives it a mass, a pure electrical mass of 1-$10^{27}$ part of a gramme, and the fundamental image of an electron is complete. This portion of electricity, identical with that on the surface of a rod of vulcanite that has been rubbed with a woolen cloth, possesses the properties of an ordinary negative charge, and when placed at a distance from another electron the usual electro-static repulsion exists. The force tending to separate them is no less than $10^{43}$ times greater than the gravitational attraction between the material particles of the above mass. The magnitudes of the electrical and gravitational forces acting when gramme portions of electricity and matter are placed one centimeter apart is that of 1-$10^{13}$ part of one pound, and $3x10^{17}$ tons. That such a force could arise in any manner whatever from such small portions of mass startles the human conception of natural phenomena.

To consider the mobility of a particle of this magnitude affected by the earth's attraction one has but to bear in mind that with its incomprehensibly small mass, a thousandth that of the hydrogen atom, its acceleration and velocity acquired in a given time will be a thousand times that of the above mentioned atom. Such particles indeed, are often subjected to forces that give rise to an acceleration of a hundred billion times greater than that due to the earth's attraction. The velocity acquired in moving a distance of five centimeters under such forces have just been indicated may easily be calculated and are found to be about $10^9$ centimetes per second. This last magnitude agrees well with the value obtained experimentally.

Proceeding now to less mystifying properties, it is important to mention one of the laws of electro-chemistry and bearing Faraday's name. This is the statement of strict proportionality between the weight of a substance liberated in an electrolytic cell and the quantity of electricity that has passed through the cell. The atoms into which a substance dissociates when placed in solution make their appearance at the electrodes when the solution is subjected to electrolysis. These atoms were early recognized as conveying charges or quantities of electricity and were called ions by Faraday. This idea of Faraday, the atom of matter with its accompanying charge is designated by the name ion.

The purpose of much refined research work has been the determination of the mass of one element deposited or liberated from solution by one coulomb of electricity. This

relation is known as the electro-chemical equivalent of the substance. The results obtained show that one coulomb will liberate 1-9660 part of one gramme of hydrogen, and of other elements in direct proportion to their atomic weight and inversely as their valency. Hence since one coulomb will separate say 1-$10^5$ parts of a gramme of hydrogen, and one atom of that element weighs $10^{-24}$ gramme, it follows that the same quantity of electricity will set free $10^{19}$ atoms. Reciprocally, one atom of hydrogen will be liberated by 1-$10^{19}$ part of a coulomb. This then may be considered the charge of the atom —the electrical part of the ion. The ratio of charge to mass is of importance and may be approximately given as $10^4$.

It was in connection with the study of the electrical conduction in rarefied gases that the most interesting, momentous, and beautiful revelations and discoveries were made. This field has been assiduously investigated by Crookes, Lenard, Roentgen, Thomson and many others.

As the result of a long series of striking and remarkably beautiful experiments with vacuum tube phenomena, Crookes in 1877 conceived the idea of there being a fourth state of matter and which be called the radiant state. It appeared that the discharge in the highly rarefied gas assuming new properties and the rotation of the vanes of Crookes' famous radiometer lent weight to the idea. In experiments of this class it was early found that both the region adjacent to the electrode by which the current left the vacuum tube, called the cathode, and the electrode itself were possessed with important properties. The cathode is the seat of a kind of rays,— rays that travel away perpendicularly from the electrode and are of the nature of particles of some sort shot off into the vacuous space. Invisible themselves, they give indication of their existence by producing a phosphorescence on impinging the glass wall of the tube or by heating a target of platinum properly located, as at the focus of a concave electrode. A most remarkable and unexpected phenomenon was found to result from the bombardment of the platinum target by the cathode rays or particles; namely, the production of a distinctly different kind of radiation known as Roentgen Rays.

It was early discovered that the cathode rays could be deflected by a magnet; and this in accordance with the electromagnetic theory of Maxwell demonstrated that the radiation was an electric current and was therefore constituted of moving charges. This idea is in accord with the fact that the cathode particles can be shown to possess motion and carry charges.

With these properties and others in mind, J. J. Thomson sought to determine the speed and the value of the mass-charge ratio, that is, the electro-chemical equivalent. The former was found to be about 1-10 that of the velocity of light and the latter 1-1000 of that of the electrolytic electro-chemical equivalent of hydrogen. Later and more refined research along this line gave v the value $4.5 X 10^9$ cm. per second (the velocity of light is $3 X 10^{10}$ cm. per second), and the charge—mass ratio for the cathode ray particle was found to be greater than $1.01 X 10^{-7}$ and less than $1.55 X 10^{-7}$ (the charge—mass ratio for hydrogen, as has been stated, is $10^4$). Different methods by independent investigators gave results that agreed surprisingly well considering the experimental difficulties involved.

It was further discovered that these values were independent of the kind of residual gas in the tube, and this itself was a fact of greatest importance as it attested that the ray particles were of a substance or character that was different from anything heretofore known.

The charge—mass ratio of the cathode particle gives no indication as to the actual magnitude of its two factors and to solve that problem called for work of the highest scientific order. It is to J. J. Thomson that the interesting and elaborate experiments which give the values of the charge and mass of the particle are due. The charge was found to be the usual ion charge, $1\text{-}10^{20}$ part of one coulomb, while the mass was only 1-700 part of the hydrogen atom, the smallest previously known portion of matter. Thus it is seen that the actuality of the masses of far less magnitude than atoms, has been definitely established. The importance of this event in the scientific world can hardly be overestimated. A simple calculation reveals the size of this negatively charged cathode particle, which we may now call by its own name, electron, which is about $1\text{-}10^{13}$ part of a centimeter in diameter, or only 1-100,000 of the size of an atom in linear dimension.

In connection with the above statements, it will not be without interest to include a few numerical relations which are due to Sir Oliver Lodge. Simple computations show that to provide an atom of hydrogen with its proper mass, and that by giving it electrons, would require about seven hundred of the latter. In the case of an atom of sodium, which is twenty-three times as heavy as hydrogen, 23X700 electrons would be required, and in the case of mercury no less than 100,000 electrons.

The presence of 100,000 electrons occupying a space of $10^{-9}$ centimeters in diameter leads to the consideration of the density of such an atom; for, without a little calculation, one might think that the electrons were highly crowded. On the contrary, however, the occupied space within the boundary of the atom has a volume ten thousand million times greater than the volume of the swarm of electrons. Thus even in an atom which may be termed dense, there is no appreciable degree of crowding; in fact, the electrons are proportionately no closer together than are the planets of the solar system. By taking one of the theorems of the modern theory of gases as our starting point, it is easy to ascertain that the average length of an electron's free path, moved over without encountering another electron is a billion times its own diameter. The length of this free path in other atoms will be correspondingly greater or less in proportion to the density of the atom in question.

In the case of an electron traveling from the cathode and striking the platinum electrode as in the Roentgen ray tube, the distance of penetration will be of the order of a thousandth of a millimeter. Thus it is that the Xrays are practically generated at the surface of the electrode, and can emerge with but small loss of power. The actual stoppage of an electron in the last portion of the thousandth of a millimeter, and the negative acceleration incidental to the impact of the electron upon an atom such as platinum, will be $10^{23}$ times as great as the value of the gravitational acceleration. The force required in the present case would be one-tenth of a dyne. Likewise the power required, which is easily calculated from the simple equation, (force X distance) divided by time = power, or introducing the numerical values $10^{-1}X10^{-8}$ divided by $10^{-17}=10^{8}$ ergs per second.

The energy set free in such encounters may be dissipated in various ways, as heat manifested by the heating of the target, or as radiation in the form of X rays. Larmor, who mathematically investigated this portion of the subject has shown that the fraction of the total power set free and which will be radiated is given by the ratio,

$$\frac{rv}{dV}$$

where **r**, **d**, **v**, and **V** are respectively the electron's diameter, the distance passed over by the electron in its stoppage, its normal velocity, and the velocity of light. If the electron be moving with a velocity of a tenth of that of light and if stoppage

occurred in its own radius then about twenty per cent of the energy set free by the impact would be radiated, the remainder would be taken up as heat by the atoms surrounding the bombarded atom.

Further consideration leads to the irrefutable conclusion that the electron is unit quantity of electricity, nothing more. It occupies the same position in the electron theory that the atom does in the atomic theory; it is the indivisible fundamental electrical quantity. The time may come, and that in the not far distant future, when the atomic theory will be revised or completely altered and based entirely on the electron.. Even from the present status of the subject, there are indications that the properties of ordinary matter may quite logically be explained by the aid of the electron and its properties.

In all of the preceding discussion our attention has been taken up with the negative charge and sight has been lost of the positive electricty. Regarding the latter, our knowledge is comparatively meager though what is known is of great bearing on a complete understanding of the subject.

In experimenting with a vacuum tube having a perforated cathode, Goldstein came across a new type of rays in the space back of the cathode rays. Canal rays was the name given to the new phenomenon. Wien proved that they were only slightly deflected by a magnet, and that they were moving particles possessing positive charges. Their velocity was found to be $3x10^7$ centimeters per second, more than a hundred times smaller than the electron's speed. The charge to mass ratio was about $10^4$ which is the same as that of the hydrogen atom with its accompanying charge as observed in electrolysis; that is, the hydrogen ion. In the case of the other gases the value is the same as that of the corresponding electrolytic ion. In other words, these particles with positive charges are nothing else than ions.

The interpretation of these facts leads to the conclusion that positive charges are always associated with the chemical atoms, thereby constituting ions. On the other hand the negative particles are sometimes removed or torn off an atom just as if they were mere appendages or loosely attached parts. It will also be seen that the ion, or positive unit, can by no means be as agile or attain such a speed as the electron, burdened as it is with an atom which constitutes a portion of its makeup.

Thus it is realized that the negative electron can exist distinctly separate from ordinary matter whereas the positive

electricity, possibly positive electrons, if there be such, are always associated with matter and as yet no experimental evidence to the contrary has been encountered. The mass of the electron has been shown to be of a purely electrical nature, and whether or not the atom itself will reveal a constitution that is also wholly electrical remains unknown.

In the early part of this article, it was explained how the self-induction of the moving charge, or as later named, the electron, was responsible for its inertia and some years ago Heaviside first showed the inertia increased at high velocities. Later investigation has indicated, however, that although the involved equation gives the inertia an infinite value when the speed reaches that of light, other factors, such as the finite size of the actual particle, enter into consideration and alter the above conclusion. A conclusive experiment of Kaufman showed that the charge to mass ratio increases as the velocity approaches that of light and since it is too improbable to suppose a change in the charge, it follows that the mass increases. This result is in accord with the supposition that the mass is of purely electro-magnetic origin.

Since the electrons, by reason of the electro-magnetic laws involved, possess properties that perfectly simulate inertia and thus a fundamental property of matter, nothing stands in the way of supposing that matter consists of anything other than systems or complexities of electrons. Hence it may be accepted that the material atom is nothing but an ordered arrangement of a certain number of positive and an equal number of negative electrons, and that the latter in whole or in part move about the mass center of the atom in the same manner as astronomical bodies.

The positive ion may be considered as an atom from which one or more negative electrons have been detached, and the negative ion may be looked upon as an atom possessing one or more extra negative electrons.

The present theory of matter will without a doubt give way to one based on the electron. The nature of the electron itself is not and may never become any more known than that of the atom of Dalton. The ultimate or absolute nature is probably even beyond the scope of human explanation and understanding.

In conclusion, it is to be recognized that the electron is the fundamental element and unit on which is based a theory that bids fair to explain and correlate in wonderful and positive manner all of the phenomena encountered in the domains of physics, chemistry, and electricity.

## BOOK REVIEWS.

STEAM POWER PLANT ENGINEERING. By G. F. Gebhardt, Professor of Mechanical Engineering, Armour Institute of Technology. John Wiley & Sons, New York. A. C. McClurg & Co., Chicago. Pp. 816, illustrations 461, 8vo. Cloth, $6 net.

To those graduates of Armour Institute of Technology who were privileged to be in Prof. Gebhardt's classes, no introduction to this book is necessary, since the mechanical engineering students at this college, for some years past, have been aware of the painstaking and detailed work of its preparation. The subject of power plant engineering has been treated in a systematic manner with power plant apparatus as a unit of division. In addition to these careful studies of types of apparatus, there are included chapters on operation, finance and economics, testing apparatus and methods; and for reference purposes, typical specifications, and the complete standard engine and boiler trial code of the American Society of Mechanical Engineers.

The book is characterized by a conciseness of diction that permits an enormous amount of material to be included in the 816 pages. On this account no adequate review of its contents can be undertaken; but it is without question the finest work in its field, and undoubtedly the last word on power plant equipment, operation, testing, or design.

Two features make the book unique among the general run of engineering literature. The illustrations, 461 in number, were prepared especially for this book, and present an exceptionally fine appearance. These have been drawn with special reference to the subject matter, and are a distinct relief from the customary catalog cuts and familiar engravings so often used in engineering books. The other feature is the very complete bibliography pertaining to the subject matter, that is included after each paragraph and chapter. This has been brought strictly up to date, and we notice careful elimination of obsolete references. The feature is particularly valuable to the student and engineer since it permits unlimited extension of study.

It is rarely that we have examined a book covering its own subject matter in a more authoritative and satisfactory manner, and we predict for it a ready adoption as the standard for engineering college classes, and for the reference library of the engineer.

ELECTRICAL ILLUMINATING ENGINEERING. By Wm. E. Barrows, Assistant Professor of Electrical Engineering, Armour Institute of Technology. McGraw Publishing Co., New York. A. C. McClurg & Co., Chicago. Pp. 216, illustrations 135. 8vo. Cloth, $2 net.

There is no branch of electrical engineering that has developed at a more rapid rate than has the field of illumination. Within the last five years a large number of new illuminants have been introduced, which as light sources are many times more efficient than the older types. Along with this development of the source has come also an increasing knowledge as to the best manner of use of the lamp so as to obtain the most satisfactory illumination. These two developments have given rise to the modern Illuminating Engineer, a specialist of increasing usefulness and necessity.

The book of Professor Barrows is a very desirable addition to the literature of this subject. It presents in convenient form the data required in the practice of the Illuminating Engineer, as well as sufficient explanation to enable its satisfactory use as a class room text book. The chapter headings include: Light and Color, Units of Illumination and Photometry, Photometry and Photometers, Spherical Photometers and Integrating Photometers, Standards of Illuminating Power, Incandescent Lamps, Arc Lamps, Flaming Arc Lamps, Vapor Lamps, Shades and Reflectors, Illumination Calculations.

In addition to its value to the Illuminating Engineer, the book is admirably adapted for use by the electrical engineer who is not an illumination specialist, but who desires an up-to-date working knowledge of the present status of the field of illuminating engineering.

# NEW LABORATORY EQUIPMENT.

## Department of Electrical Engineering.

Since the publication of the last annual catalogue of Armour Institute of Technology, a number of valuable additions have been made to the equipment of the Dynamo and Electrical Laboratories. The experimental apparatus for high voltage work has been rearranged to give greater facilities for testing. A switchboard has been installed consisting of two generator panels and two feeder panels, which control 15,000 volt Westinghouse solenoid operated oil switches. Other equipment on this board comprise potential transformers and series transformers, for the ammeters and voltmeters, overload relays, etc.

A Northern Interpole Variable Speed motor of fifty horse power capacity has been provided for operating the experimental alternators which are controlled by the above mentioned board. The motor is equipped for starting with a Cutler Hammer Heavy Duty starter, with intermediate carbon plate rheostat between the usual grid speed notches. This enables extremely close speed control. The motor is arranged for direct connection to a 45 K. W. Westinghouse 60-cycle 1100-volt alternator, and to a 30 K. W. Fort Wayne 25-cycle 110-volt A. C. and 180-volt D. C. double current generator. This motor can also be belted to the 133-cycle Wood alternator. For exciting the various alternators, there has been installed a Burke Electric Company's motor generator set.

In the electrical laboratory, a Leeds and Northrup A. C.-D. C. Comparator for standardizing ammeters and voltmeters of alternating current type, has been purchased. The photometry room has added one Ulbrich's Spherical Photometer, one Sharp-Miller Photometer, eleven Holophane globes and reflectors, a Flaming Arc lamp, and a Westinghouse Magnetite Arc lamp. In the instrument room a number of wattmeters, ammeters, etc., for various purposes have been added.

## Department of Chemical Engineering.

The department of Chemical Engineering has, during the year, purchased or built and installed the following equipment:

A complete plant for the manufacture of sugar from raw sugar beets or cane, consisting of: One diffusion battery of five bronze cells with brass connecting tubes; capacity of the bat-

tery about 20 lbs. of dried beets or cane, equal to 65 or 70 lbs. of raw material. In connection with the battery, there is a set of cast iron tanks, heated by steam, which are of sufficient capacity to handle the diffusion juices for liming and carbonating.

One filter press and mont-jus, built to order and having a filtering surface of approximately 8 sq. ft. One steam heated vacuum pan, suitable for vacuum concentration or distillation. One steam heated open pan, capacity 5 gallons. One 10 in. centrifuge with bronze basket. One McMullen drying kiln, with drying surface of approximately 80 sq. feet.

An ore crushing and sampling plant, built to order by the Sturtevant Mill Co., consisting of: One 2x6 roll jaw crusher; one set of laboratory rolls; one disc pulverizer; one mechanical screen with screens of 40, 60, 80 and 100-mesh; one mechanical ore sampler. This, combined with apparatus already installed, forms a very complete plant for commercial assaying.

An entire set of apparatus for the study of metallography, consisting of:

One power polishing machine, built to order and designed for the polishing of metallurgical specimens for microscopic examinations; one microscope built to order for metallographic work; one photomicrographic camera.

Miscellaneous apparatus, consisting of: One 4-jar laboratory pulverizer for fine grinding of pigments, cement, chemicals, etc., built by the Abbe Mill Co.; one rotary vacuum pump built by the same company; one platinum-lined calorimeter built to order by Kolbe of Berlin; one assay balance sensitive to 1-5000 of a milligram, with multiple rider carrier attachment built by Ainsworth of Denver, one of the finest on the market; six Becker balances for students' use, and one Sartorius balance, capacity one kilogram; one Fric polariscope, as built for the United States custom service; one radiation pyrometer; one Le Chatelier pyrometer; one electric furnace, designed for carbon combustions; one set of twelve electrically heated ether extraction apparatus; one barometer; several sets of analytical and button weights (guaranteed); one Pilot tube with differential gauge; one recording pressure gauge.

In addition to the above articles of permanent equipment, the apparatus of the department has been largely augmented by the addition of apparatus for lecture experiments in General Chemistry: A number of lantern slides for purpose of class illustration; sets of graduated instrumets, calibrated by Reich-Anstalt, and a very complete line of analyzed chemicals and

fine glassware for analytical work. The import order for beakers, bottles, glassware, and chemicals for the past year totaled about $5,000.00.

Continual additions are being made to the permanent equipment apparatus, much of it being designed in the department and built to order. It is the idea of the department to have an equipment in this line second to none.

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### Department of Mechanical Engineering.

A number of important additions to the equipment of the Mechanical Laboratory of Armour Institute of Technology have been made during the past year. A standard Master Car Builder's Drop Testing Machine with its accessories, has been installed in an enclosure near Thirty-third and Dearborn Streets. It is used for all customary acceptance and research tests on car couplers, draft gears, bolsters, car wheels, and axles. A 200 sq. ft. Multi-Flow Surface Condenser, with 8 in. by 10 in. Edwards Air Pump have been purchased. These in connection with the present extensive equipment along these lines, offer unequalled facilities for research in the department of steam engineering. For the hydraulic department, a Direct Connected Motor Driven Dayton Single Stage Centrifugal Pump has been added. For the Gas Engine Laboratory a Manograph Optical Gas Engine Indicator for use with engines of extremely high rotative speed has been purchased. A standard Rattler for abrasion tests on paving block also adds to the laboratory facilities along these lines. In addition to the apparatus mentioned above, an assortment of thermometers, pyrometers, calorimeters, gauges, etc., aggregating about $4500 in cost has been purchased for the Mechanical Laboratory during the last year.

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## THE ENGINEERING SOCIETIES.

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### Mechanical Engineering Society.

During the last half-year, this society has enjoyed the most prosperous year of its existence. At the first meeting, October 13, 1908, Mr. George A. Grassby, '09, gave a talk, "The Development of the Motor Cycle." On November 10, Mr. A. Johnson, Chief Engineer of Mandel Brothers' service plant, gave an illustrated description of the up-to-date system of power plant accounting which has been adopted by his firm. Samples of many log forms which are required to be filled

out by the operating engineers and the type of power plant bookkeeping, devised by the speaker, were shown and explained in detail.

Mr. J. L. Spitzglass, '09, gave a paper November 24, on "Modern Gas Production," which was followed by an extended discussion. At the last regular meeting of 1908. Mr. H. W. Jones, Engineer The People's Gas Light and Coke Co., and one of the foremost gas engine experts in the country, gave a talk on "High Compression in Gas Engines." All his remarks were confirmed by actual test data obtained from gas engines in or near Chicago. The speaker dwelt at some length on the failure of the gas engine builders to properly recognize the advantages of high compression, and reiterated his published offer of being able to secure greater efficiency with all ordinary gas engines by increasing the compression. He also deplored the lack of data as to those pressures which will give the greatest efficiency, and offered all possible assistance to students who would undertake experiments along this line.

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## Armour Institute Branch, American Institute of Electrical Engineers.

An account of the various papers and the ensuing discussion at these meetings has already appeared in the Proceedings of the American Institute of Electrical Engineers, and therefore but a brief statement is given herewith.

The papers presented during the last semester are as follows:

Storage Battery Booster Systems.
By P. G. Downton, '09. — Oct. 1, 1908

Electrons.
By G. E. Marsh. — Oct. 15, 1908

Selection of Railway Motor Equipment.
By G. I. Stadeker, '09. — Nov. 5, 1908

Operation of Substations of the Commonwealth Edison Company's System.
By E. W. Petty, '09. — Nov. 19, 1908

Alternating Current Single Phase Commutator Motors.
By Tracy W. Simpson, '09. — Dec. 3, 1908

Design of Conduit System for Multiple Office Telephone System.
By A. P. Strong, '09. — Jan. 7, 1909

The paper of Mr. G. E. Marsh, "Electrons," was the basis for the article by the same writer that appears on another page.

### The Armour Civil Engineering Society.

The lectures at the meetings of this society have been extremely well attended and have been undoubtedly of great benefit to the hearers. The program for the last semester is as follows:

Construction of the Halsted Street Bridge.
By J. C. Penn, '05. Bridge Department, City of Chicago. Oct. 20, 1908
(This was illustrated by lantern slides, and many practical points of construction were presented.)

Reinforced Concrete Building Construction.
By Ernest McCullough, C. E., Mem. W. S. E. Nov. 17, 1908
(In this lecture, especial stress was laid on the use of various practical formulae for designing beams.)

Concrete Construction for Shops and Stations.
By E. H. Hiller, '06, Division Engineer, The Chicago Railways Co. Dec. 1, 1908
(Blue prints were shown of many of the new buildings of the Chicago Railways Co., and lantern slides showed construction progress.)

Some Engineering Problems.
By R. S. Spaulding, '06, Assistant Engineer Water Pipe Extension Dept., City of Chicago. Dec. 15, 1908

Sewage Purification.
W. S. Shields, C. E., Sanitary Engineer. Jan. 12, 1909

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### THE SENIOR CHEMICAL SOCIETY.

At the first meeting of the Senior Chemical Society, Prof. H. McCormack gave a very fine paper on "The Part of the Chemist in Industrial Work." The paper dwelt with work done in the past in the conservation of our natural resources by the aid of the industrial chemist. Many features were brought up which were entirely novel to the hearers, and in the discussion following, the speaker gave many personal incidents on the subject.

At the next meeting, Prof. B. B. Freud presented the subject of "The Chemist and Society." The speaker took up the position now occupied by the ordinary chemist in society, and gave incidents showing the position due him according to the quality of his work. The paper did much to inspire enthusiasm in the younger members of the audience. At the last meeting, Mr. E. W. McMullen read a paper on "New Methods of Sugar Refining," which took up the new methods now being tested at the Institute, and their probable effect on the sugar industry.

# THE ARMOUR ENGINEER

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**The Engineering College and the Large City.**

The location of a College of Engineering in a big industrial city has obvious advantages, many of which cannot be over-estimated. The great engineering projects as a rule originate in and emanate from the large cities; here are found the great industrial manufacturing plants, showing the application of the principles of engineering in all of its phases, and here may be seen and inspected the most modern and up-to-date methods of engineering practice.

In the electrical and mechanical fields are the latest types of power plants equipped with the most efficient machinery; here also are to be found the latest developments in electric traction for both urban and interurban railways. The offices of the telephone companies, showing their intricate and complicated systems of exchange, are always open for inspection to those interested in this particular line of engineering. Electro-chemistry and illumination are branches of electrical engineering which are fast being developed principally, in the cities.

Chicago, as a type of an engineering city, has much to offer. The new steel plant at Gary, Indiana, has in its gas power and gas producer sections, the best models of their kind probably in the world. These, together with the perfected processes of ore handling and steel manufacture, make this one of the most interesting and instructive places for the mechanical and chemical engineer. The Pullman Car Works, the International Harvester Company's plants. the various electrical. and machinery manufacturing companies are illustrative of the opportunities for the inspection and study of the very latest technical appliances. designed by the most capable engineers.

The civil engineer is in constant touch with the different phases of municipal engineering development. including bridge building. sewer systems. pumping stations. railway, hydraulic, and sanitary engineering. There are to be found at any time in all stages of construction. the different types of bridges, masonry, concrete and steel structures. sewers, water supply systems, subways and tunnels.

There probably have been more new processes of manufacture developed along the line of chemical engineering than any other branch of the profession. Especially is this noticeable in industrial chemistry and its association with engineering problems. There is no other city as able to provide the varied examples of manufacturing involving chemical processes as Chicago. The stock-yards. with its various plants, including fertilizer. glue. glycerine. pepsin. and soap works; the different by-products companies; paint. white lead. and varnish works; breweries and distilleries; gas works; steel, smelting and refining. and cement plants; food products and sugar making companies; oil refineries and glass works, are some of the places which are always of interest to the chemical engineer.

For those interested in fire protection and fire prevention, the City of Chicago offers exceptional facilities in the Underwriters' Laboratories. the only laboratories of their kind in the United States. In addition. the municipal organization, including the fire department, with its alarm and telegraph systems,

fire boats, etc.; the insurance survey bureaus, the Board of Underwriters, as well as the fire insurance companies themselves, invite inspections of the ways and means of fighting fire found only in a live manufacturing city.

To say nothing of educational facilities provided by a school for the study of architecture, it is patent even to the layman that the place to study building in all of its phases is where building is being done. There is not a time of the year but what can be found in Chicago and its environs any type of structure or building that is of interest to the student of architecture. Suburban residences, city dwellings, modern apartments, churches, theaters, libraries, factory buildings, manufacturing plants, stores, and hotels, can be seen and inspected in any stage of erection and whenever desired.

To all of the above and more, the student of engineering in a big city has easy access and it forms no inconsiderable part of a liberal technical education. The inspection trip is looked upon by technical educators as having an educational influence of no mean value. Students of engineering departments of universities and colleges of engineering within a radius of five hundred miles of Chicago make annual trips to this great industrial city for purposes of inspection, but their investigations are necessarily casual and limited on account of the short time allowed for leave of absence from their regular college work. To obtain the greatest value from inspection visits, the student should wait until his junior and senior years. While these visits at the beginning of a college course are of value in inciting a spirit of interest in engineering, there is sometimes a disposition on the part of the student to make the trip a sort of junket and an outing rather than a serious occasion for the collecting of valuable practical information. These matters, however, are left to the discretion of the instructor who usually accompanies the students and who judges at what period of the course certain trips are to be made. Great value is attached to the opportunity given to senior students in the investigation of subjects assigned to them for graduating theses. They often spend weeks and even months in power plants and engineering offices collecting data which are invaluable to them not only for thesis material, but which can be used in after life

in the practice of their profession. Managers and superintendents of works are usually very willing to give permission for this detailed investigation, and in many cases they get information from students which is of practical benefit in raising the efficiency of their plants and which they have not taken time to investigate thoroughly before.

Here again the city student has the advantage. In many cases, on account of his intimate and continued association with engineers and with those in charge of engineering projects, power plants, manufacturing industries, etc., he has unconsciously paved the way for the offer of a good position after leaving college. When the employer of engineers wishes to increase his force of assistants, it is certainly much easier and more satisfactory to be able, through the use of the telephone, to find a candidate ready to present himself prepared for work, within a few hours, than it is to waste time in correspondence with a school of engineering many miles away. During prosperous times, the demand for engineers is great, and the college of engineering in a big city has unusual facilities to obtain employment for its graduates. And again, the undergraduate student need have little trouble in finding employment to defray the expenses of his college course. There are many ways and means in a city like Chicago for the young man who is determined to realize his ambition in the acquisition of a college education. We hope in the near future to have some data, systematically arranged, with reference to this subject, and it should form an interesting and helpful bit of information.

There is another side of student life in a big cosmopolitan city which should appeal to those who desire something more in their college career than merely enough to prepare for the practice of their profession. Here the student is able to come into association with the best life of every kind. The mightiest life of the nation pours into the city. Here the best preachers have their pulpits; here the best lecturers bring their messages; here the best influences of art and music, and of every form of noble enjoyment cluster; here the association of man with man is more intimate and more formative of the best character. It is also said that the enjoyment of

nature is more intense to one who spends a part of his energies and time amidst the works of man than to one who is remote from the most active human interests. But with all the opportunities and educational facilities offered by the big city, the best that the college can do is to *fit* the young man to *prepare* for the practice of his profession. Whether the young man will make a successful engineer depends entirely upon himself, and the manner in which he takes advantage of his opportunities. If the college has done its duty to the student and the student has done his duty to the college, the result should be that the boy who came as the verdant, unsophisticated freshman should leave at least a gentleman, more or less of a thinker and a scholar, a citizen of honor to his alma mater and to his country. The successful engineer must be a man of true and loyal instincts, for nature is imperious, and those who use her tools for their handicraft must make obeisance to her majestic commands.

H. M. RAYMOND.

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**Valuation for Taxes and for Rate of Return**

The amount of taxation of a public utility company by a municipality is a determining factor in the charge for its product which the company must make in order to insure for itself a rate of return on investment commensurate with the more or less hazardous nature of the business.

Assuming that the charge for service is regulated by means of a commission, or otherwise, to such a low amount as to permit only this reasonable return to the company, it is at once apparent that the addition of a tax burden will necessitate an increase of rate of charge and vice versa In the case of a public utility company which serves all of the people of a given city, it is evident that as far as city taxes are concerned, the case is one of the company's paying back to the consumer on the one hand through the medium of taxes, while taking an equivalent amount on the other from the consumer by an increase of charge. Hence the taxation of a public utility com-

pany which has its rates regulated by a commission is merely one of trading dollars with no gain to anyone, but rather a loss due to cost of the transaction.

City taxation of street railway, lighting, or water companies which provide utilities used throughout the city is in the category above stated. In the case of state taxes of a city company, or city taxes on a property which only benefits a portion of that city, such as, say, a short railway, a ferry company, or companies which are in the same business but of different size and segregated territorially; the conclusion as to the advisability of eliminating taxes is not altogether valid, since it is proper to collect a small charge from the user of such a utility to apply on the cost of the whole government by virtue of which the company does business locally.

In such cases the important question arises:—Shall the rate of taxation be based on the same property valuation as is that upon which the allowable rate of return on investment is based by the regulating commission?

It has been suggested by an engineer who is interested in these problems that the taxable valuation of a property should be its replacement value depreciated to present condition, whereas the rate of return should be allowed on the total valuation of the property to the owner, which will include physical and intangible values. This is strictly in line with the idea, to use a homely comparison, that the old horse is taxed at a valuation independent of its having been nursed all its life by an expensive veterinary and at present idle, or of its having been continuously employed in lucrative teaming since its maturity, provided its replacement value is the same in the two cases.

Taxation on total valuation does not seem reasonable in the light of the above statements.

On the other hand, it is necessary that the allowable rate of return to the utility should be on a total valuation which represents the value of the property to its owner, and is made up of physical and intangible valuation, the various items of which have been so carefully analyzed by H. C. Abell. (THE ARMOUR ENGINEER, Jan. 1909.) The value of a property to the owner is different from its value to the community it

serves, and it is just and reasonable that the rate of return be allowed on its value to the owner; i. e., total valuation; and for taxing purposes, on its value to the community; i. e., its depreciated replacement value.

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**Reorganization on the Basis of Public Utility Commission Valuations**

The exellent analysis of the total valuation of a property as presented by H. C. Abell (THE ARMOUR ENGINEER. Jan. 1909) shows it possible to prove a total valuation greater than the replacement value by a large percentage.

Certain of the items listed in this analysis have given rise to much debate as to their proper inclusion in an estimate of total valuation. These are:

"The loss due to operation until the utility is on a paying basis."

"The loss in interest and profits on the investment from the first operating period to a time when expenses and interest are earned."

It has been suggested that the unrestrained inclusion of these items would lead to excessive valuations, since they offer a means of making up for bad judgment on the part of the original promoter. There is no doubt, however, that a certain amount of this class of charge is reasonable, especially so if any of the securities were of the cumulative dividend class.

When a property is being refinanced, and rates are being adjusted and securities exchanged under the control of public utility commissions, the question is very important as to how much of these intangible value factors may be reasonably included, for it is certain they can be included to excess.

A tentative plan which has come to our notice provides that bonds shall be issued to an amount equal to three fourths of an amount which shall be the replacement value of the property plus the cost of putting the property in first class operating condition. Stock shall then be issued for an equal amount, so that the total securities will be one and one-half times the physical valuation of the reconstructed property. The charge for service would then be adjusted to give a reasonable rate of return on this total security. The margin of fifty per cent would cover in most cases the in-

tangible values, and yet serve to limit the abuse of the factors of intangible valuation as noted above. The exact plan of financing in any particular case would follow this tentative plan with such modifications as are warranted by local conditions.

With such conservative financing the underwriting charge would be very small, and the stock holders would receive a return on investment well above the bond interest rate. This should certainly be the case considering the nature of the public utility business. The plan is commendable and worthy of notice since it provides an efficient compromise between the conflicting interests involved.

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**Track Capacity and Rapid Transit Service**

The question of urban transportation in the large centers of population is one of the most important engineering problems of the present day. It possesses so many diverse factors, is so closely related to the development of the city and to broad questions of finance and public policy, that only a master mind is capable of grasping the innumerable complexities of the problem. Nevertheless the determination of a comprehensive plan for the development of urban transportation should be a part of the work of every city government, since it is only by careful study of this sort that mistakes can be avoided. It is significant that all the large cities at present have one or more engineering boards, transportation committees, or similar bodies, which may report on the subjects either to the city or to commercial associations. It is proper that such work should be done by these public representatives since an operating company can hardly be expected to have constantly in mind the broad view point of a properly constituted public commission which is advised by high class engineering talent.

Among the problems to be taken up by such an engineering organization is that of providing maximum possible facilities for travel per dollar of invested capital. In no case is this more important than for underground and elevated systems which by their nature are expensive to construct, and which offer at best but a fair return on investment. An important means of

attaining this result is by so distributing the investment that the "use factor" of all parts of this system shall be the same; that is, it is poor economy to build a subway or elevated road, the track of which will carry more cars per hour than can be loaded at the stations. Furthermore every part of the system should be closely examined in order that no limiting points such as badly arranged signals, track crossings, etc. shall occur. In addition every attempt should be made to increase the specific carrying capacity at all points in order that the peak load carrying ability will be highest possible. The habit of city residents in America is to travel in the morning and in the evening, hence the importance of high peak capacity from the standpoint of company as well as of passengers.

The analysis of conditions obtaining in present subway or elevated railway systems is probably most important, since these roads form the customary trunk line by which the city worker travels to and from business, doing so on account of their relatively greater speed. They have been the means of upbuilding large sections of formerly unoccupied territory, and the traffic density is usually abnormally high. It is generally realized that even with such enormous peak traffic as these lines possess, they are not unqualified financial successes, and any means of increasing peak carrying capacity should be welcomed by the owners of such roads.

Also on this account the design of new transit systems should be carefully scrutinized, and an estimate of maximum carrying capacity should be a part of all designs and plans, and then in conjunction with the traffic load factor, the financial success or non-success can be reasonably ascertained.

Until recent years the design of rapid transit systems of the elevated and subway class was rarely undertaken with this idea in mind of estimating the peak carrying capacity, but experience has shown that the heavy investment at stake makes such determination vital to the success of the project.

The business of a transportation system should be to carry passengers, and the consideration of speed should be subservient thereto. It is interesting to note that for most conditions, the maximum carrying capacity of a system is attained when the trains are operated at a speed much below that in present

general use in the subway and elevated roads of the country. The present speed has been an important item in developing the territory through which the road travels, and an increase of car capacity by decreasing speed of trains much below present actual rush hour speeds should not be permitted. In this connection, it is interesting to note that the "reservoir station" system as proposed by Bion J. Arnold for conditions at New York City, provides the highest "critical speed" of any of the numerous proposed methods of increasing carrying capacity. By "critical speed" is meant that value of maximum speed of trains at which the system should be operated to give the highest car capacity.

Mr. Thos. A. Banning Jr., in his analysis of this reservoir station capacity on another page shows this critical speed at which the carrying capacity of the system (station and track combined) is greatest at about 35 miles per hour, for the assumed constants of operation used in his study, which are very close to New York Subway conditions. This fact is an important argument for the adaptability of this system of building subways to New York conditions.

This article by Mr. Banning is by far the best discussion of the problem of carrying capacity that we have ever seen, and it deserves to be read with interest. Some work of this nature has been done by the engineers having in charge the equipment with electricity of Der Berliner Ring und Stadtbahn and by the Interborough Rapid Transit Company in a study made of conditions previous to the opening of the Brooklyn extension, but there has never been published anything approaching this analysis in completeness. A knowledge of train dynamics together with rational assumptions as to operating constants is the means of leading to definite and determinable answers to questions that heretofore have been hazy and ill defined. For any system having trains operating over tracks with stations at known distances apart, with trains driven by motor equipment of known characteristics, and with station stops controlled so as to be reasonably constant, a definite answer can be found to the question, "What is the car capacity?" The methods are invaluable for the analysis of present systems and for forecasting the working out of any proposed means of operation of present or unbuilt transportation systems.

# THE HYDROMETER IN THE OPERATION OF STORAGE BATTERIES.

BY L. H. FLANDERS.*

Instructions written several years ago for the operation of storage batteries frequently laid great stress on the determination of the end of charge and discharge by the cell voltage on closed circuit. Examples are: "Never discharge below 1.8 volts per cell." "Stop the charge when the voltage reaches 2.5 volts per cell," and various other modifications of the same idea. Even at the present time the voltmeter is often considered the one adjunct in determining the end of discharge and charge.

The average person concerned with storage batteries has the above voltage idea so firmly fixed in his mind, and has so little conception of what really takes place in the cells, that the battery is sometimes ruined, even when the instructions are conscientiously followed. Therefore, while recognizing the desirability and even necessity of using voltmeter readings to arrive at the condition of a battery, it is the purpose of this article to show that the true condition of a battery can be learned only by the use of the voltmeter in conjunction with the hydrometer.

The changes taking place in the lead storage battery during discharge and charge are shown, for practical purposes, in Fig. 1 where the essential elements are represented diagrammatically. In the charged battery (1, Fig. 1) the active material, peroxide of lead ($PbO_2$), supported on a lead conducting framework, is the positive electrode, sponge lead ($Pb$), supported on a similar framework, is the negative electrode, and a mixture of sulphuric acid ($H_2SO_4$) and water ($H_2O$) is the electrolyte.

When the circuit is completed by turning on lamps (2, Fig. 1), current flows from the positive plate through the lamps into the negative plate, through the solution back to the positive plate. Due to electrolysis, the positive plate gives up its oxygen and is converted into lead sulphate ($PbSO_4$). The negative plate is also converted into lead sulphate, and water is formed from the oxygen of the positive plate and the hydrogen of the sulphuric acid.

This action continues until the amount of sulphate formed on both plates cuts off the remaining active material from the action of the current and electrolyte (3, Fig. 1).

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*Class ~~1908~~. Engineer, Storage Battery Department, Westinghouse Machine Company, East Pittsburgh, Pa.

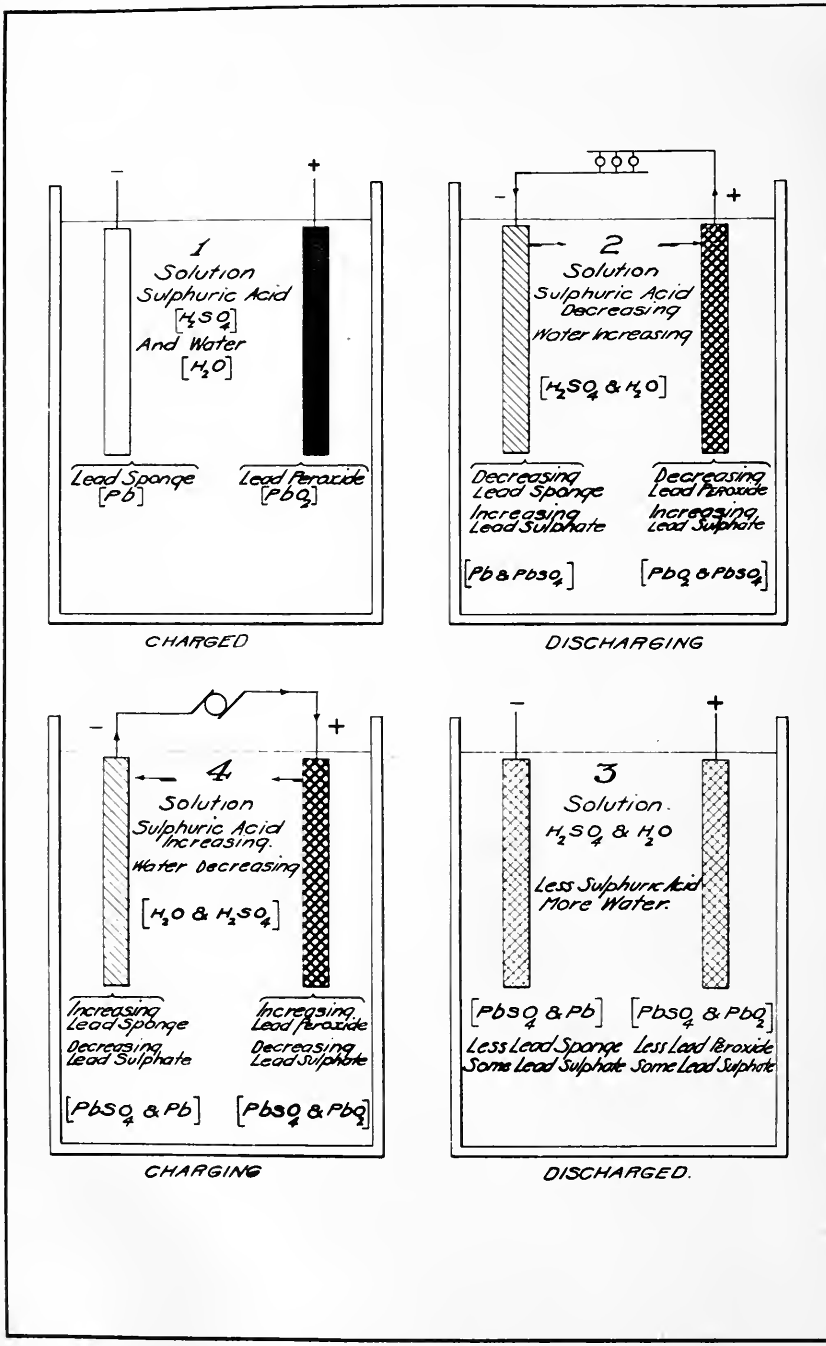



FIG. 1. SHOWING REACTIONS IN LEAD STORAGE CELL.

If the positive and negative terminals of a generator be connected respectively to the positive and negative terminals of the battery, current flows from the generator into the positive. through the solution to the negative plate, back to the generator (4, Fig. 1). Here the action which takes place is the reverse of discharging. Sulphate from both plates unites with hydrogen of the water to form sulphuric acid. and. as a result, the negative plate is reduced to a lead sponge and the positive plate is oxidized to lead peroxide. At the end of the charge the battery is, theoretically, in the same state as at the beginning of discharge, shown by 1, Fig. 1.

The above explanation of the action in a storage battery is known as the sulphation theory, and is now generally held to be correct. It may be expressed by the equation:

$$Pb+PbO_2+2H_2SO_4=2PbSO_4+2H_2O.$$

Reading from left to right represents discharging and from right to left charging. For a detailed analysis of the reactions in a storage battery, those interested are referred to "Theory of the Lead Accumulator", translated by Dr. Carl L. von Ende from the German of Dr. Friedrich Dolezalek.

According to the above theory and Faraday's Law, for each ampere-hour put into the battery on charge, there are formed 3.66 gr. of sulphuric acid, and there is absorbed 0.672 gr. of water. Conversely, for each ampere-hour taken out of the battery on discharge, the solution loses 3.66 gr. of sulphuric acid and gains 0.672 gr. of water. This means that, if the decrease in the amount of sulphuric acid in the solution can be measured, the ampere-hour output can be determined.

The change in the amount of sulphuric acid and water in the solution affects the density in direct proportion to the change in acid. The hydrometer, measuring the change in density, therefore, indicates the amount of change in the sulphuric acid content of the solution, and hence indicates the ampere-hours necessary to produce such change, provided the initial volume, initial density and final density be known. For, at a temperature of 70° F.:

Let $V_1$ = initial volume of solution in c. c. = 4250 c. c.
$V_2$ = final volume of solution in c. c.
$S_1$ = initial specific gravity of solution = 1.200
$S_2$ = final specific gravity of solution = 1.164
$P_1$ = per cent sulphuric acid for s. g. $S_1$ = 27.7%
$P_2$ = per cent sulphuric acid for s. g. $S_2$ = 23.05%

($P_1$ and $P_2$ are obtained from tables, such as Lunge and Isler's tables of densities and percentage strength of mixtures of sulphuric acid and water.)

Y = ampere-hour output or input to produce s. g. $S_2$

Then in the case of discharge:

$3.66Y$ = weight of acid absorbed,

$V_1S_1P_1/100$ = initial weight of acid

$V_2S_2P_2/100$ = final weight of acid

and $$3.66Y = (V_1S_1P_1/100) - (V_2S_2P_2/100) \qquad (1)$$

but $V_2S_2$ = final weight of solution in grams.

$0.672Y$ = weight of water formed in grams,

$V_1S_1$ = initial weight of solution in grams,

$(V_1S_1P_1/100 - V_2S_2P_2/100)$ weight of acid absorbed in grams

then

$$V_2S_2 = 0.672Y + V_1S_1 - (V_1S_1P_1/100) + (V_2S_2P_2/100)$$

$$V_2S_2 = \frac{0.672Y + V_1S_1\,(1 - P_1/100)}{1 - (P_2/100)} \qquad (2)$$

Substituting (2) in (1), thus eliminating $V_2$ and simplifying

$$Y = \frac{V_1S_1\dfrac{P_1 - P_2}{100}}{3.66 - (3P_2/100)} \qquad (3)$$

Substituting the numerical values given above for the practical case:

$$Y = \frac{4250 \times 1.2 \times \dfrac{(27.7 - 23.05)}{100}}{3.66 - \dfrac{3 \times 23.05}{100}}$$

79.8 ampere-hours have been taken out. For the same initial volume and range in gravity 80 ampere-hours were actually taken out on test. (See Fig. 2.)

From this calculation it is apparent that, if the initial volume and specific gravity of the solution of a particular storage battery cell be known, the hydrometer for this particular cell could be given a scale reading directly in ampere-hours instead of a scale reading in specific gravity.

The foregoing discussion and calculation have assumed a constant given temperature. For the range used in storage battery work, the specific gravity of sulphuric acid solution varies inversely as the temperature about three points for each ten degrees Fahrenheit. That is, sulphuric acid of S. G. 1.200 at 60° F. would have a gravity of 1.197 at 70° F., or

1.203 at 50° F. Furthermore, the available ampere-hour capacity of a cell varies markedly with a change in temperature; thus a cell working at the normal rate at 30° F. instead of 70° will have only 70% of its former capacity. Therefore, in taking account of hydrometer readings, the temperature always should be noted, and, to secure good results in the use of the hydrometer, the cell should be operated at as near 70° F. as possible.

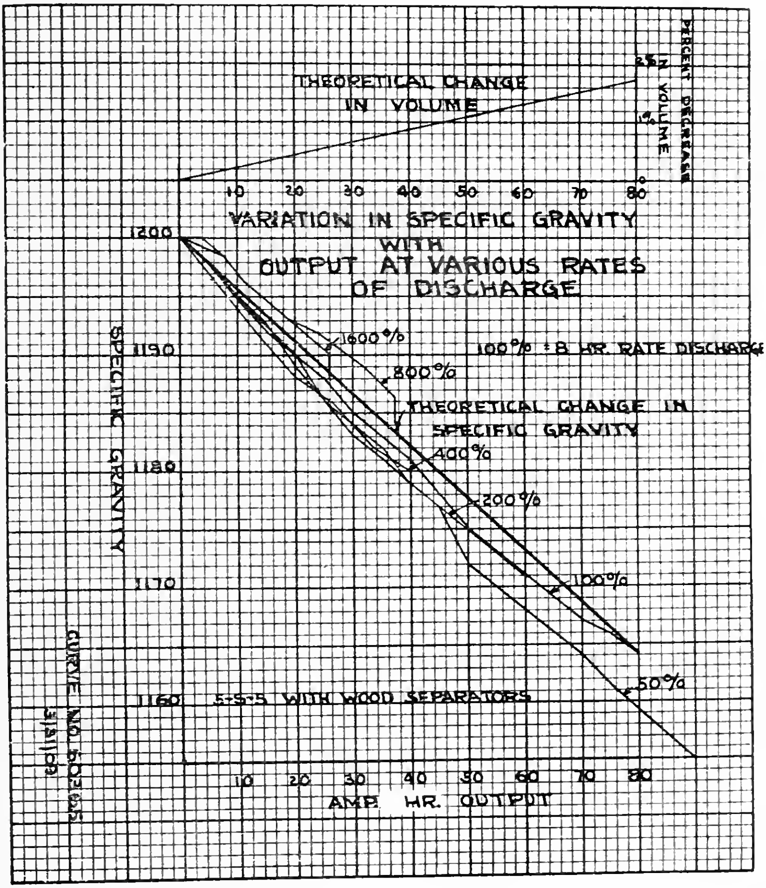



Fig. 2.

While the above calculation shows that, theoretically, the hydrometer should be an exact indicator of the ampere-hours taken out of or put into a storage battery, Lyndon makes the following statement: "In practice the variation in density of electrolyte with ampere-hours discharged does not conform

to the theoretical, unless the discharge rate is very low, and the higher the rate of discharge the less is the diminution in density for a given output.'' Further on, referring to the same subject, he states: '' These experiments show conclusively that the theoretical laws do not hold except at discharge rates so low as to be impracticable.'' With the last statement the writer cannot agree, for, as further shown by Lyndon, this variation between the theoretical and actual amount of change

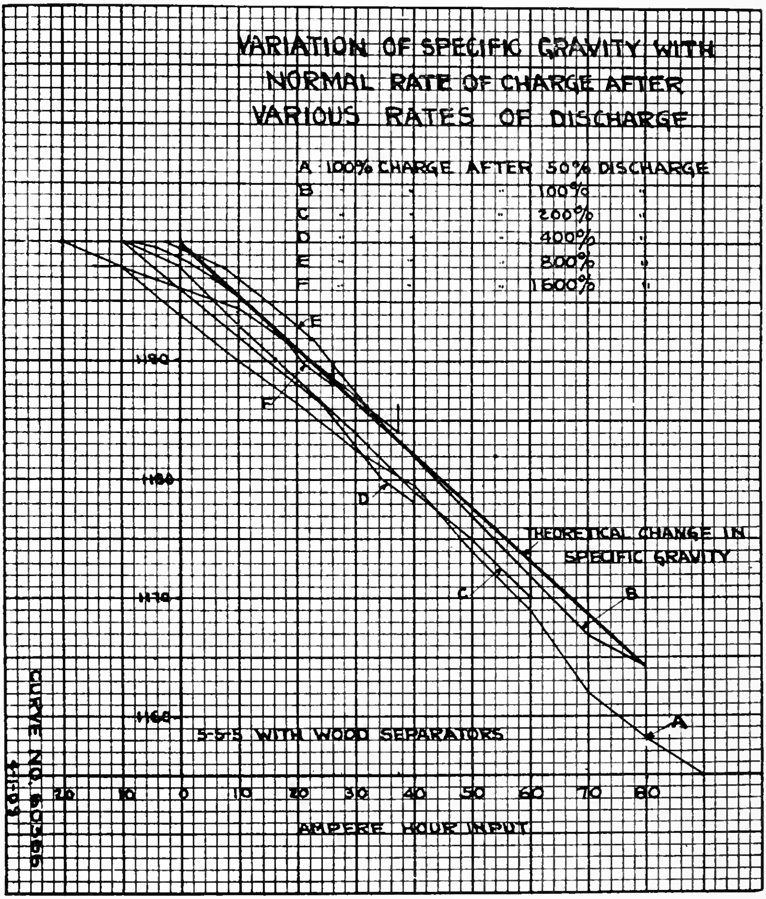



Fig. 3.

in density is dependent primarily upon the diffusion of the electrolyte. This diffusion varies with the particular type and design of plates; a Planté plate, with a large surface and thin layers of active material accessible to the electrolyte, provides better diffusion than a thick plate of dense pasted ma-

terial. Furthermore, the concentration changes of the acid within the pores of the former plate will be less than in the latter, and the variation of capacity with different rates, accordingly, will be less. That the actual variation of capacity or ampere-hour output with change in specific gravity of the solution conforms sufficiently closely with the theoretical vari-

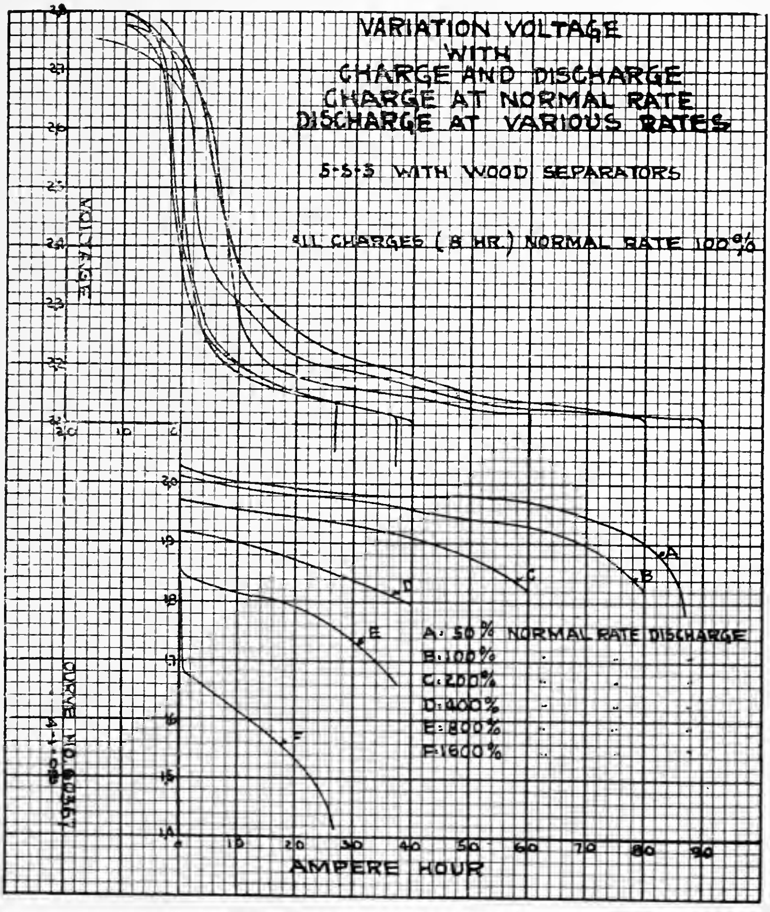



FIG. 4.

ation to make the hydrometer a very satisfactory means of determining the condition of the battery through continuous and intermittent periods of output and input at various rates, is shown, for at least some types of cells, by the curves, Fig. 2, Fig. 3, and Fig. 5.

To obtain these curves a number of cells of a commercial Planté type (Fig. 6) were tested at a constant temperature of 70° F. at various rates of charge and discharge, while the change in specific gravity was measured every few minutes by an accurate hydrometer. The separators used consisted of sheets of wood veneer, 1/16 of an inch thick, held against the negative plates by means of wood ribs. The cells used were of 80 ampere-hour rated capacity at the 8-hour or normal rate. Also a number of cells from 40 to 560 ampere-hours capacity were tested, and all conformed very closely to the 80 ampere-hour cells, though only the results obtained from the 80 ampere-hour cells are shown in the curves. The rates of test varied from 27% to 1600% of the rated 8-hour rate, or from 0.0021 of an ampere to 0.1248 of an ampere per square inch of grid surface, or from 0.011 of an ampere to 0.67 of an ampere per square inch of the total vertical sections of the electrolyte between the plates, in the plane of the plates. The grid surface is $5\frac{1}{3}$ times the total projected positive plate surface.

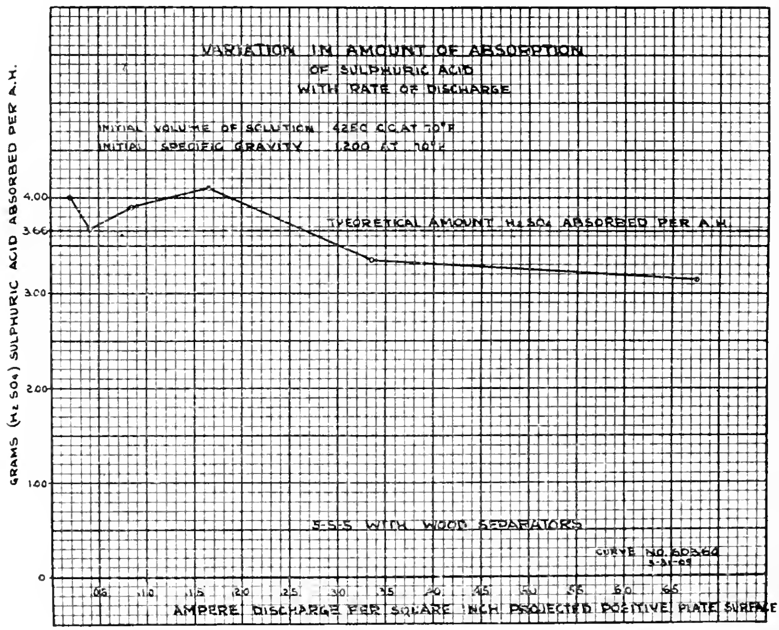



Fig. 5.

Fig. 2 shows the variation in specific gravity, with output, at various rates of discharge. It also shows the percentage decrease in volume.

Fig 3 shows the variation of specific gravity for the 100% (8-hour) rate of charge after the discharge recorded in Fig. 2. At the 400%, 800%, and 1600% rates of discharge, the specific gravity continued to drop from 2 to 2½ points after the discharge was stopped in the half hour intervening before the cells were recharged.

Fig. 4 shows the voltage variation for the above tests. As the abscissae in Figs. 2, 3, and 4 are ampere-hours, the time of discharge may be obtained by dividing by the rate, taking 10 amperes as normal 100%.

Fig. 5 shows the variation of amount of sulphuric acid absorbed with rate of discharge.

These tests were conducted under approximately commercial conditions, for no effort was made to secure especially close readings other than those that could be secured by the ordinary storage battery attendant. Furthermore, while a maximum variation of 14% from the theoretical value is shown in Fig. 5, in the commercial working of cells this amount of variation would not impair the use of the hydrometer to determine the state of charge or discharge; that is, whether the battery is fully charged, ¾ discharged, or half charged, etc.

In some classes of installations, such as isolated lighting plants or railway interlocking plants, the battery is discharged intermittently at moderate rates, and continuously at very low rates, the discharge sometimes extending for days and even weeks between charges. With the volume of acid usually available, the voltage remains very nearly constant until near the end of discharge and then falls rapidly, so that when the work is intermittent, and the average rate of discharge is low, a greater amount of lead sulphate may be produced than that formed by the eight hour normal rate for the normal time. Of this greater amount of sulphate the voltage gives no indication, although such a condition of over-distcharge should be known and remedied, as it is very injurious to the battery.

The effect of over-discharge on the positive plates of Planté cells is that the reserve lead supporting the active material (lead peroxide) of the plates is subject to attack, and therefore during the next charge an increased quantity of active material is formed, with a consequent reduction in the amount of available lead. If this continues, the active portions of the positive plate will be entirely converted into active material, and the plate will disintegrate long before it would have, if only a small amount of sulphate had been formed during each discharge. In pasted types of positive plates, over-discharge produces large masses of isolated sulphate that are not accessible to the current, and, as lead sulphate occupies approximately 1.8 times the volume that the equivalent peroxide does, the

grids of over-discharged plates occasionally crack. Over-sulphation of negative plates tends to cut down the efficiency, especially in the case of pasted types, since masses of sulphate poorly accessible to the charging current are apt to be formed. To reduce this isolated sulphate prolonged charging is required

That this sulphation is indicated by the hydrometer and is not shown by the voltmeter may be proved by the following results. A cell, after being discharged at the rate of 27% of

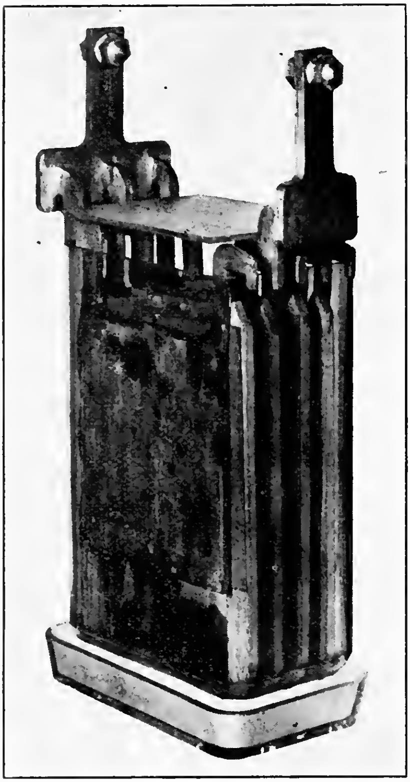


Fig. 6. 80 Amp. H R. Cell.


HYDROMETER.
Fig. 7.

the normal for 38 hours, showed a voltage of 1.88 at the end of discharge, while the ampere-hour output was 102.6. The initial specific gravity of the solution was 1.200 and the final 1.155 (both at 70° F.) showing the change in specific gravity to be 0.045 for 102.6 ampere-hours. Referring back to Fig. 2, the final specific gravity was 1.164 after a cell had been discharged at the normal rate for the normal time with 80 ampere-

hours output. As the initial specific gravity in this case was also 1.200, the change in gravity was 0.036 for 80 ampere-hours output. Comparing 0.045 and 0.036 we have 45/36 or 1.25 as much sulphuric acid absorbed during the 102.6 ampere-hours output as in the normal discharge. Theoretically 102.6x3.66 gr. or 375.5 gr. of sulphuric acid would be absorbed during the larger output, and 80x3.66 gr. or 292.8 gr. during the normal discharge: and, comparing, we have 375.5/292.8 or 1.28 as much acid abosrbed during the 102.6 ampere-hours output as in the 80 ampere-hours discharge. Thus the sulphation shown by the hydrometer differs very little from the theoretical sulphation. On the other hand, referring to Fig. 4, the voltage is shown at the end of a normal discharge to be 1.82 for an output of 80 ampere-hours, and discharging at 50% of the normal rate to be 1.90 for an output of 80 ampere-hours. In other tests (not shown in Fig. 4), after discharging at 27% of the normal rate, the voltage is 1.96 for an output of 80 ampere-hours, and is 1.88 when 102.6 ampere-hours have been obtained. In the first three cases, for the same output (80 ampere-hours), different voltages are shown; while, in the last case, the voltage is 0.06 higher for 28% greater output than in the first case. Therefore, under the conditions of low or intermittent discharge the voltmeter is useless in determining when the discharge should be stopped to prevent over-sulphation, and the hydrometer is the instrument which should be depended upon.

Neither can the voltmeter alone be used to correctly determine the end of charge, for, by referring to Figs. 3 and 4, it will be noted that the voltage at the end of charge is not the same in any two cases. In a badly sulphated cell the voltage might rise to a maximum and stationary value without the completion of the lead sulphate reduction. The hydrometer alone will show this condition.

Even on open circuit, sulphation of the active material is caused by local action due to impurities. This condition will be recognized at once by the low specific gravity when hydrometer readings are taken, although the open circuit voltage is normal.

Storage batteries are often unnecessarily charged. This prolonged charging, resulting in ebullition, is injurious, because the violent agitation produced by the gas bubbles tends to detach particles of active material and thus to shorten the life of the positive plates. Readings of the hydrometer will prevent this, for they show when the specific gravity is restored to approximately its original value.

In operating cells by the specific gravity method of charge and discharge, it is, of course, impracticable to keep track of each cell in the battery: so for each set of cells working in series, one of the cells, preferably the weakest, should be selected as a pilot-cell. This pilot-cell should be equipped with an automatic cell-filler to automatically replace the water lost by evaporation, a thermometer, and an accurate hydrometer.

Fig. 7 shows a suitable hydrometer, capable of being easily read to one point divisions and having a scale correct at 70° F. It should be flat and not over 5/16 of an inch thick, so that it can be operated between the plates and thus be more sensitive to the density changes in the vicinity of the plates than it would be if operated between the plates and the jar, as is customary. The pilot-cell in large installations is provided with a hydrometer which has a contact-making device and relays, so that, when the gravity reaches a desired lower limit, a bell is rung, and a red lamp is lighted. When the gravity reaches a desired upper limit, a bell is rung, and a green lamp is lighted.

Fig. 8 illustrates a simple cell-filler which can be made from standard chemical apparatus and applied to any cell. A glass cover with four holes is provided for the cell. Through one of the holes, a thermometer supported by a soft rubber bush extends into the electrolyte, and the hydrometer is inserted through a second hole, between the battery plates. On the glass cover is placed a Wolf bottle having one opening near the bottom and two on top. The lowest opening is connected to a tube with a stop-cock, which extends through the third hole in the glass cover almost to the bottom of the battery plates. From one of the upper openings, an air-tube with a bulb passes through the fourth hole of the cover and terminates below the level of the electrolyte, at a distance of about one per cent of the depth of the electrolyte when the cell is fully charged. Under the end of this tube and resting on the top of the plates, is a watch-glass to prevent gas from rising into the water bottle. With the stop-cock shut off, the bottle is filled nearly full with water; the stopper is then put in and the stop-cock opened. Water flows from the bottle into the cell until the level rises so as to shut off the air-tube. If the level, due to evaporation, drops below the air-tube, air passes into the bottle and water flows into the cell until the level is restored. Theoretically, the level should not be kept constant, for it has been shown that the volume of the electrolyte decreases about 1¾% for a normal complete discharge in the particular cells that have been subjected to test in the foregoing discussion. The cell-filler, therefore, will keep the level constant only between certain limits dependent upon the

change in charge and discharge volume. That this variation does not make enough difference to commercially affect the result is shown in Figs. 2, 3 and 5.

To operate a battery by means of a pilot-cell. it is primarily necessary that the range in specific gravity for the particular type of cell, with a given initial volume of electrolyte for a complete discharge at the normal (8-hour) rate, should be obtanied from the manufacturers or by test.

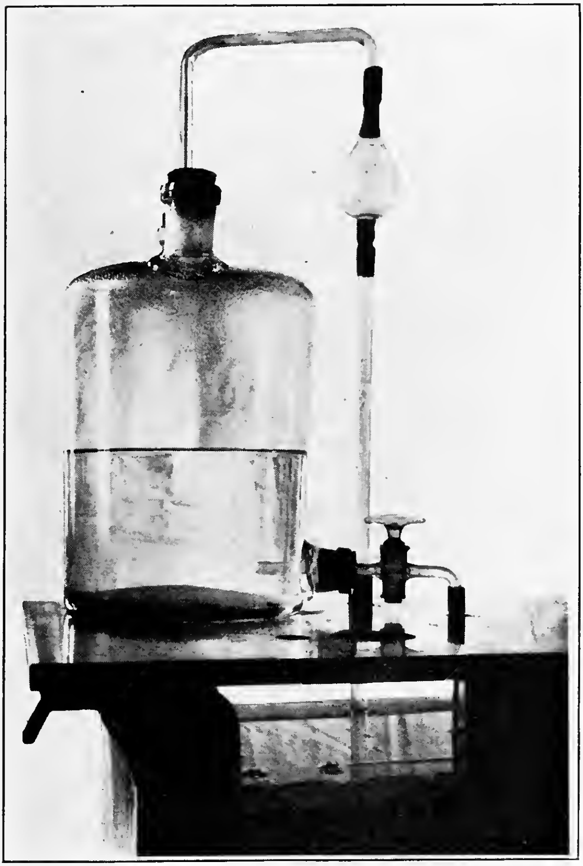


FIG. 8. AUTOMATIC PILOT CELL FILLER.

Secondly, specific gravity and temperature readings from the pilot-cell should be systematically taken and recorded.

Furthermore, the operation by pilot-cell presupposes that all the other cells of the series are in the same condition as the pilot-cell. In order to maintain this condition, it is necessary

Fig. 9. Regulating Battery Showing Signal Hydrometer and Cell Filler.

to give a careful overcharge at regular periods, once a week, once in two weeks, or at least once a month, according to the kind of service or type of battery. But, as before stated, the battery should not be needlessly overcharged. The overcharge should be given at the normal rate, which should be cut down to 50% toward the end, and should be continued for two hours after the gravity and voltage cease to rise. Before starting the overcharge, the level of the electrolyte should be adjusted to the standard height by the addition of distilled water. At the

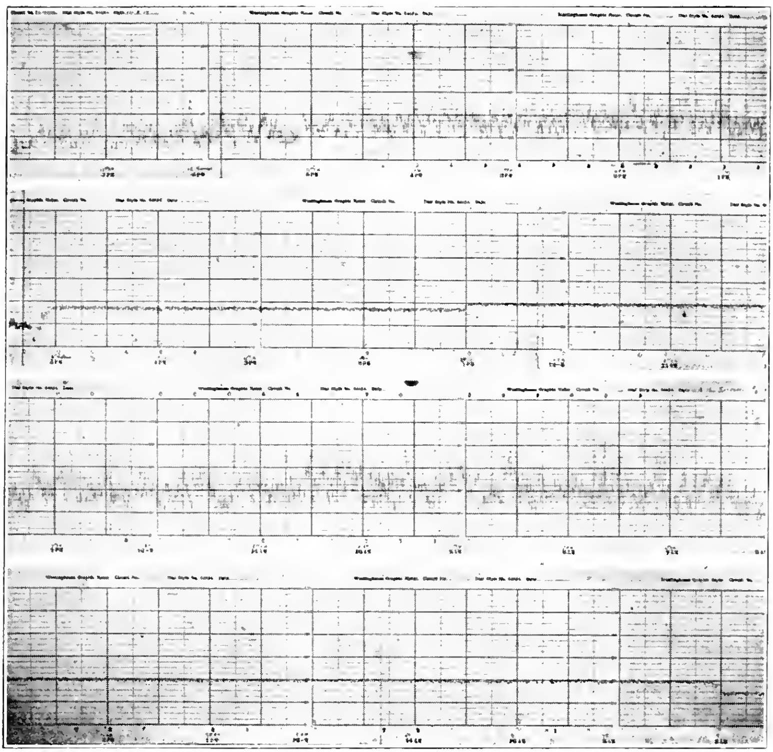
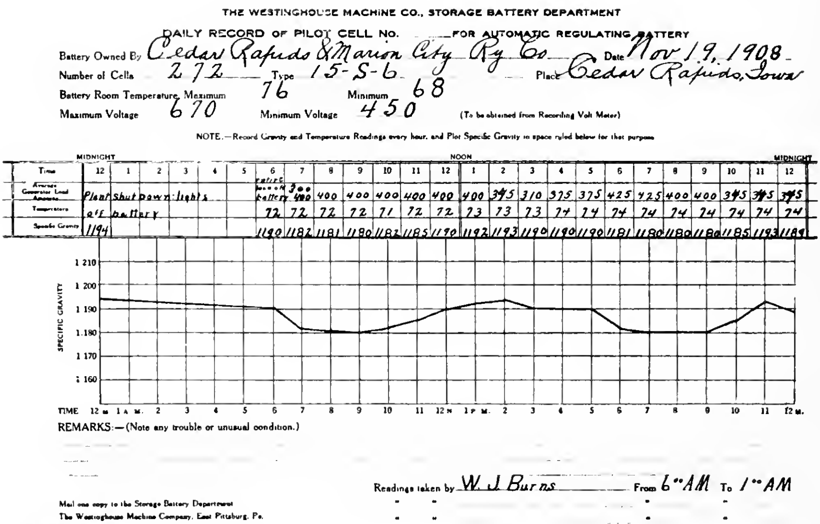


FIG. 10. GENERATOR AND EXTERNAL LOADS WITH REGULATING BATTERY.

end of the charge, voltage readings should be taken on all cells with the current flowing, and then, after a period on open circuit, the specific gravity of the electrolyte should be measured and compared with the results obtained on preceding overcharges. Any variation in gravity over three or four points should be investigated, particularly if the gravity be low. If no solution has been spilled, this low gravity is probably due to either short circuits or local action caused by impurities. During overcharge the voltmeter is a valuable adjunct in de-

termining short circuits, for, in a cell, a voltage markedly lower than that of adjacent cells indicates something wrong.

In the case of isolated lighting or railway interlocking plants, when the gravity has dropped ⅓ to ½ the normal range, the cells should be recharged to the gassing point, then discharged the same number of points drop from the preceeding charge value as on the first discharge, then again recharged to the gassing point and so on until the gravity reaches, on discharge, the minimum normal value. An overcharge should then be given. For example, if the normal range of specific gravity is from 1.200 to 1.164, or 36 points, and a 15 point variation will do the work, it is far better to discharge 15 points, recharge until the cell begins to gas, and so


THE WESTINGHOUSE MACHINE CO., STORAGE BATTERY DEPARTMENT

DAILY RECORD OF PILOT CELL NO. ____ FOR AUTOMATIC REGULATING BATTERY

Battery Owned By Cedar Rapids & Marion City Ry Co. Date Nov 19, 1908

Number of Cells 272 Type 15-S-6 Place Cedar Rapids, Iowa

Battery Room Temperature, Maximum 76 Minimum 68

Maximum Voltage 670 Minimum Voltage 450 (To be obtained from Recording Volt Meter)

NOTE.—Record Gravity and Temperature Readings every hour, and Plot Specific Gravity in space ruled below for that purpose

| Time | 12 (MIDNIGHT) | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 (NOON) | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 (MIDNIGHT) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Average Generator Load Amperes | Plant | Shut | Down: lights | | | | entire load on battery | 300 400 | 400 | 400 | 400 | 400 | 400 | 400 | 345 | 310 | 375 | 375 | 425 | 425 | 400 | 400 | 345 | 345 | 345 |
| Temperature | off | battery | | | | | 72 | 72 | 72 | 72 | 71 | 72 | 72 | 73 | 73 | 73 | 74 | 74 | 74 | 74 | 74 | 74 | 74 | 74 | 74 |
| Specific Gravity | 1194 | | | | | | 1190 | 1182 | 1181 | 1180 | 1182 | 1185 | 1190 | 1192 | 1193 | 1190 | 1190 | 1190 | 1181 | 1180 | 1180 | 1180 | 1185 | 1193 | 1189 |



REMARKS:—(Note any trouble or unusual condition.)

Readings taken by W. J. Burns From 6 AM To 1 AM

Mail one copy to the Storage Battery Department
The Westinghouse Machine Company, East Pittsburg, Pa.

2109 3m 10-08

FIG. 11. DAILY PILOT CELL RECORD.

on until the final gravity reaches 1.164, and finally to give the cell an overcharge, than to give a series of discharges until thegravity reaches 1.164 and one complete recharge. It is impractical to always give the overcharge when the minimum gravity is reached, so that an overcharge should be given periodically, depending upon the particular conditions under which the battery is operated.

In automatic regulating batteries, such as Fig. 9, where a booster and regulator are used to maintain constant load upon the generating system, and where the battery takes the fluctuating load, the change in generator load is determined by the change in specific gravity of the pilot-cell. Referring

to Fig. 9, the signaling hydrometer and automatic cell-filler are shown on top of one of the cells. Fig. 10 shows the typical generator and external load. The battery in this plant is worked partly discharged, in order to prevent gassing at high rates and consequent depreciation and low effeciency, because of the high charge rates when the load is light. The daily pilot-cell record (Fig. 11) with the load curves (Fig. 10) admirably show the advantage of operating by means of the hydrometer. Hourly readings of the specific gravity of the

THE WESTINGHOUSE MACHINE CO., STORAGE BATTERY DEPARTMENT

STORAGE BATTERY OVERCHARGE REPORT

SHEET NO 1.

Battery Owned By Cedar Rapids & Marion City Ry Co Place Cedar Rapids, Iowa Date Jan 15-1909

Number of Cells in Battery 272 Type 15-S-6 Special Battery Charging at 60-45 Amps.

NOTE: (1) Bring Electrolyte to Standard Level by Adding Distilled Water Before Starting Overcharge.
(2) Take Voltage Readings at End of Charge While Current is Still Flowing, Keeping Current Constant.
(3) Take Gravity Readings at End of Charge Just After Current is Cut Off, With Battery on Open Circuit.
(4) Be on the Lookout for any Low Cells. Investigate and Immediately Remedy Any Trouble, Giving Full Description Under Remarks.

PILOT CELL OVERCHARGE REPORT Reading to be Taken on Pilot Cell Every 15 Minutes After Cell Starts to Gas. Charge to be Continued for 7 Consecutive Readings or for 1½ Hours After Gravity Ceases to Rise.

PILOT CELL NO.______ 15 MINUTE READINGS

| Time | Temp | Specific Gravity | Time | Temp | Specific Gravity | Time | Temp | Specific Gravity | Time | Temp | Specific Gravity | Time | Temp | Specific Gravity | Time | Temp | Specific Gravity | Time | Temp | Specific Gravity |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 9.00 | 73 | 1190 | 10.00 | 74 | 1194 | 11.00 | 75 | 1196½ | 12.00 | 75 | 1197 | 1.00 | | | 2 | 76 | 1198 | | | |
| 9.15 | 73 | 1191 | 10.15 | 74½ | 1195 | 11.15 | 75 | 1196¾ | 12.15 | | | | | | | | | | | |
| 9.30 | 73½ | 1192 | 10.30 | 75 | 1196 | 11.30 | 75 | 1196¾ | 12.30 | | | | | | | | | | | |
| 9.45 | 74 | 1193 | 10.45 | 75 | 1196 | 11.45 | 75 | 1197 | 12.45 | | | | | | | | | | | |

OVERCHARGE READINGS

| Cell No | Volts | Specific Gravity | Cell No | Volts | Specific Gravity | Cell No | Volts | Specific Gravity | Cell No | Volts | Specific Gravity | Cell No | Volts | Specific Gravity | Cell No | Volts | Specific Gravity | Cell No | Volts | Specific Gravity |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 2.7 | 1205 | 19 | 2.7 | 1195 | 37 | 2.7 | 1205 | 55 | 2.7 | 1203 | 73 | 2.7 | 1200 | 91 | 2.6 | 1195 | 109 | 2.7 | 1197 |
| 2 | 2.7 | 1200 | 20 | 2.65 | 1197 | 38 | 2.7 | 1197 | 56 | 2.7 | 1200 | 74 | 2.7 | 1205 | 92 | 2.65 | 1203 | 110 | 2.7 | 1197 |
| 3 | 2.7 | 1197 | 21 | 2.7 | 1200 | 39 | 2.7 | 1200 | 57 | 2.7 | 1200 | 75 | 2.7 | 1205 | 93 | 2.7 | 1195 | 111 | 2.7 | 1195 |
| 4 | 2.7 | 1192 | 22 | 2.65 | 1200 | 40 | 2.7 | 1200 | 58 | 2.7 | 1200 | 76 | 2.7 | 1207 | 94 | 2.7 | 1197 | 112 | 2.7 | 1205 |
| 5 | 2.7 | 1197 | 23 | 2.7 | 1200 | 41 | 2.7 | 1202 | 59 | 2.7 | 1205 | 77 | 2.65 | 1195 | 95 | 2.7 | 1195 | 113 | 2.7 | 1200 |
| 6 | 2.7 | 1197 | 24 | 2.7 | 1198 | 42 | 2.7 | 1200 | 60 | 2.7 | 1195 | 78 | 2.7 | 1197 | 96 | 2.7 | 1195 | 114 | 2.65 | 1200 |
| 7 | 2.7 | 1190 | 25 | 2.7 | 1197 | 43 | 2.7 | 1200 | 61 | 2.7 | 1207 | 79 | 2.7 | 1200 | 97 | 2.7 | 1195 | 115 | 2.7 | 1203 |
| 8 | 2.7 | 1190 | 26 | 2.7 | 1200 | 44 | 2.65 | 1198 | 62 | 2.7 | 1203 | 80 | 2.7 | 1195 | 98 | 2.7 | 1200 | 116 | 2.7 | 1200 |
| 9 | 2.7 | 1195 | 27 | 2.7 | 1197 | 45 | 2.7 | 1200 | 63 | 2.7 | 1205 | 81 | 2.7 | 1200 | 99 | 2.7 | 1197 | 117 | 2.7 | 1200 |
| 10 | 2.65 | 1202 | 28 | 2.7 | 1195 | 46 | 2.7 | 1200 | 64 | 2.7 | 1210 | 82 | 2.7 | 1197 | 100 | 2.7 | 1193 | 118 | 2.7 | 1200 |
| 11 | 2.7 | 1200 | 29 | 2.7 | 1195 | 47 | 2.7 | 1200 | 65 | 2.7 | 1200 | 83 | 2.7 | 1207 | 101 | 2.65 | 1193 | 119 | 2.7 | 1198 |
| 12 | 2.7 | 1200 | 30 | 2.7 | 1195 | 48 | 2.7 | 1205 | 66 | 2.65 | 1200 | 84 | 2.55 | 1197 | 102 | 2.7 | 1200 | 120 | 2.7 | 1206 |
| 13 | 2.7 | 1200 | 31 | 2.7 | 1195 | 49 | 2.7 | 1197 | 67 | 2.7 | 1200 | 85 | 2.55 | 1197 | 103 | 2.7 | 1200 | 121 | 2.7 | 1193 |
| 14 | 2.7 | 1200 | 32 | 2.7 | 1200 | 50 | 2.7 | 1207 | 68 | 2.7 | 1197 | 86 | 2.7 | 1197 | 104 | 2.7 | 1200 | 122 | 2.7 | 1200 |
| 15 | 2.7 | 1195 | 33 | 2.7 | 1195 | 51 | 2.7 | 1200 | 69 | 2.7 | 1197 | 87 | 2.7 | 1175 | 105 | 2.7 | 1200 | 123 | 2.65 | 1190 |
| 16 | 2.7 | 1195 | 34 | 2.7 | 1197 | 52 | 2.7 | 1203 | 70 | 2.7 | 1197 | *88 | 2.65 | 1187 | 106 | 2.7 | 1190 | 124 | 2.7 | 1195 |
| 17 | 2.7 | 1200 | 35 | 2.7 | 1200 | 53 | 2.7 | 1197 | 71 | 2.7 | 1205 | 89 | 2.65 | 1200 | 107 | 2.7 | 1195 | 125 | 2.7 | 1193 |
| 18 | 2.7 | 1195 | 36 | 2.7 | 1203 | 54 | 2.7 | 1200 | 72 | 2.7 | 1200 | 90 | 2.65 | 1195 | 108 | 2.5 | 1190 | 126 | 2.7 | 1198 |

REMARKS—(Make Note of all Work Done on Battery Since Last Overcharge Giving No. of Each Cell Worked on, the Nature of Work and Reason.)

*Have done nothing to battery except keep cells filled with water*

Mail one copy to Storage Battery Department
The Westinghouse Machine Company, East Pittsburg, Pa.

Readings Taken By F. W. Laas.
Readings Recorded By

2110-500 10-08

FIG. 12. OVERCHARGE REPORT.

pilot-cell are plotted on this record. It is the aim to so adjust the average generator load that the gravity will not normally vary more than from 1.190 to 1.180, or 10 points, the normal range being 45 points. Fig. 10 shows that at 7:00 a. m. the gravity had reached 1.182, at 2:00 p. m. 1.193. At 7:00 a. m. the bell and light notified the attendant that the gravity was the desired minimum value, so that the load was raised from 300 to 400 amperes (Fig. 10) in order that the battery might receive a net charge. By referring to Fig. 13, the record of the battery voltage, the voltage is seen to be at a maximum between 1:00 p. m. and 2:00 p. m. and indicates useless gassing,

which is corroborated by the high gravity shown at 2:00 p. m. on the pilot-cell record. The operator's attention was called to this by the bell and green light, and the load was accordingly reduced to 345 amperes. By this method the battery is operated through a small range in gravity, which prevents abnormal sulphation, gives a maximum efficiency, and will result in long life.

To illustrate the advantage over the voltage method gained from operation by the specific gravity method of charge and discharge, a certain railway interlocking plant increased the efficiency approximately 18 per cent. by changing to the latter method, besides entirely doing away with trouble from sulphation.

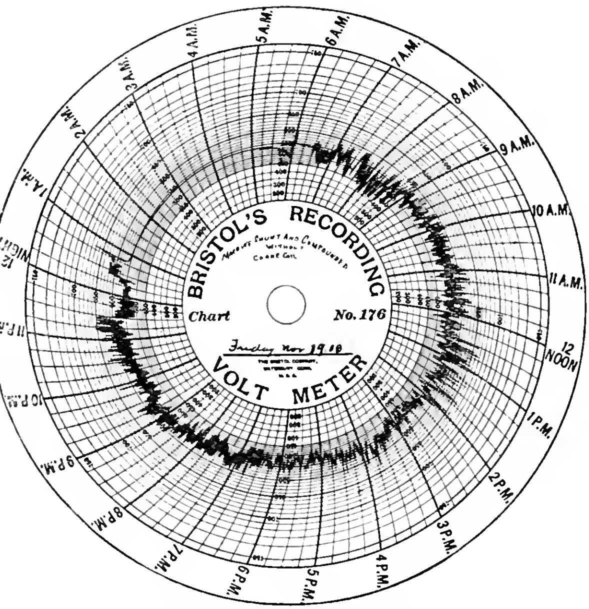



Fig. 13. Voltage Chart.

Practically as well as theoretically the hydrometer is the only reliable means for determing the state of charge or discharge of a storage battery: its use prevents over-sulphation and needless charge; and it is of great assistance in detecting the presence of impurities. Therefore, the use of the hydrometter insures a longer life and greater efficiency than can be obtained by relying alone upon the voltmeter.

## CRUSHING PLANTS.

### BY ELLIS SOPER.*

From primitive man, who, in order to secure material from which to fashion his war clubs, axes, ceremonials and other articles, built a fire against the rock and then dashed water upon its heated surface, to the modern quarry in which hundreds of tons of dynamite are exploded at one time and the rock broken into pieces often weighing five tons each and loaded by enormous steam shovels into cars, thence discharged into giant crushers which reduce these five-ton pieces to **six-inch pieces and smaller, in five seconds,** is an advance of such magnitude as to deserve much study and consideration.

The most common type of quarry and crushing plant is that which produces crushed rock for railroad ballast, road making, etc., and consists generally of small dump carts drawn by mules, or narrow gauge cars, the carts or cars being loaded by hand and dumped into a crusher, from which the material is elevated and discharged into bins or screened, as desired.

The general arrangement of the modern quarry and crushing plant operated either in connection with a mine, cement plant, or independently for ballast, concrete materials, etc., varies, of course, with the local conditions, character of the materials to be quarried and crushed, and the uses to which the product is to be put.

### COMPARISON OF ORDINARY CRUSHING PLANT VS. PLANT EQUIPPED WITH GIANT BREAKER.

We have selected for our comparisons a crushing plant of 1,000 tons capacity in 10 hours; material, ordinary lime stone of medium hardness. The prevailing practice is as follows:

Material is quarried in the ordinary manner; broken up into pieces averaging 8-in. to 12-in. cubes, loaded by hand into cars, which are hauled by mules or horses to the foot of the incline leading to the crushing plant. The car is hauled from here either by a "barney," or hoisting engine to a tipple, which automatically dumps the car into the crusher (Gyratory Type) which is capable of receiving a 16-in. or 18-in. cube of rock. From this crusher the material is lifted or discharged into rotary screens, the screened portions falling into bins, and the unscreened rock or "tailings" being either returned to the first crusher or discharged into a smaller crusher, from which the material is elevated back into the bins. Such an arrangement is shown in Fig. 1. In this sketch, a power plant is shown together with a line shaft for driving crushers, screens and elevators.

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*Class 1903. President The Soper Company, Detroit, Michigan.

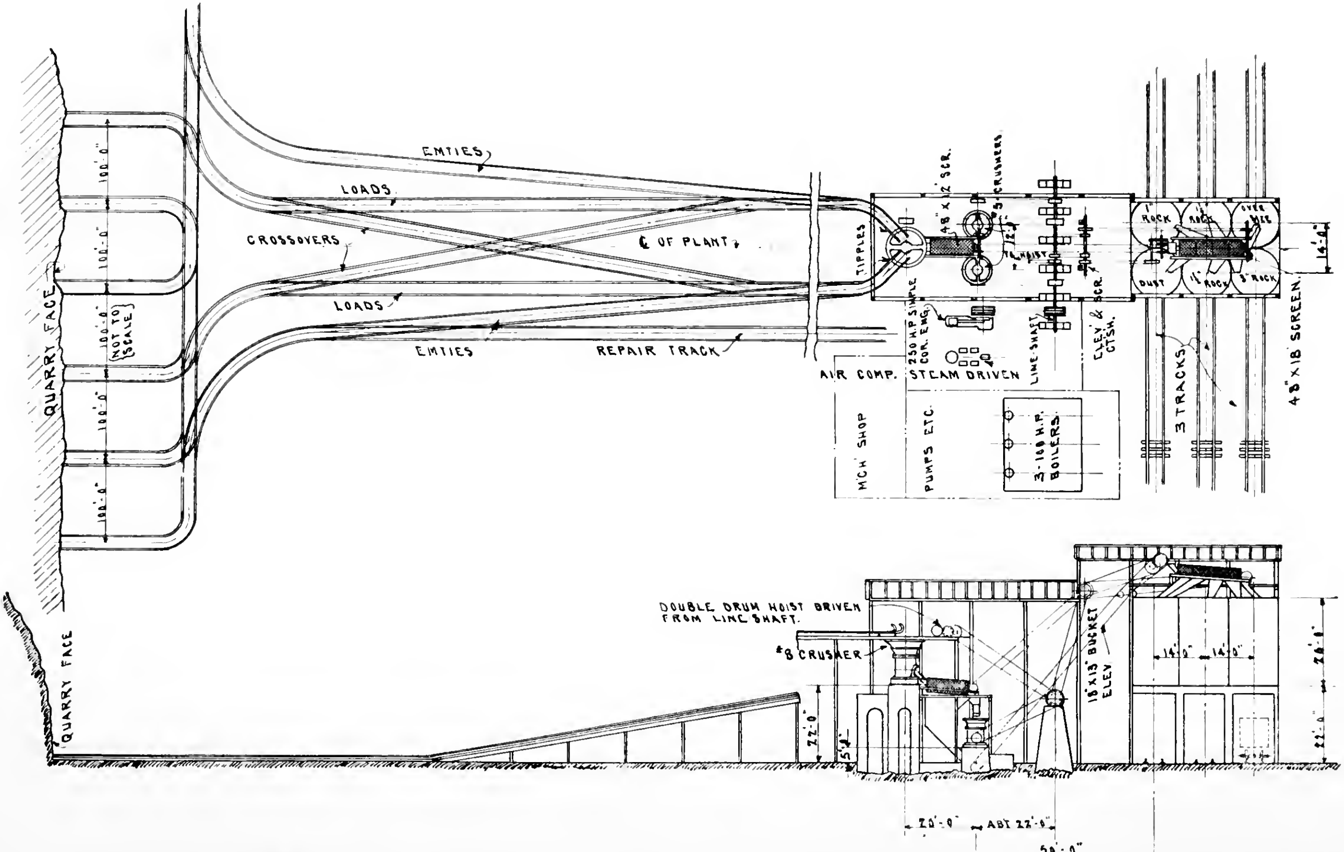
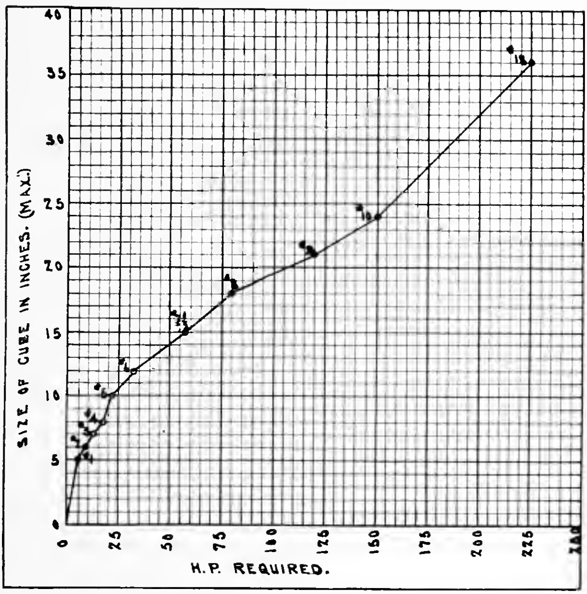



FIG. 1. PLAN AND ELEVATION OF CRUSHING PLANT WITH NO. 8 AND TWO NO. 5 CRUSHERS.

A steam-actuated air compressor is shown in the engine room, it being assumed that air will be used for drilling purposes. While it is commonly assumed that air is much cheaper than steam for drilling purposes, such is not the case. Disregarding the loss of heat energy by radiation from the steam line, it requires approximately 25 per cent more fuel to operate drills than when steam is used. If the steam pipes were covered, a much greater saving would be effected by the use of steam. However, in ordinary practice the cost of operation is about the same, and the use of air is advised if the fuel costs are not prohibitive.




TABLE

| NO. OF CRUSHER | SIZE OF CUBE INCHES. | H.P. REQUIRED. |
|---|---|---|
| 1 | 5 | 5. |
| 2 | 6 | 8. |
| 3 | 7 | 12.5 |
| 4 | 8 | 17. |
| 5 | 10 | 22.5 |
| 6 | 12 | 32.5 |
| 7½ | 15 | 57.5 |
| 8 | 18 | 80. |
| 9 | 21 | 120. |
| 10 | 24 | 150. |
| 18 | 36 | 226. |
| | | |

FIG. 2. TABLE AND CURVE SHOWING HORSE POWER REQUIRED FOR VARIOUS CRUSHERS AND SIZES OF ROCK.

Within the last few years the more progressive crushing plants have installed steam shovels for loading the rock into cars, having been forced to do this in many instances because of the unreliability of the quarry labor. The result has been a decided decrease in the cost per ton of loading, but the rock must be broken into small pieces as when loaded by hand in order that the crusher will not become "clogged."

The manufacturers, realizing that the so-called "No. 8" crusher would not admit a rock over an 18-in. cube, designed and put upon the market a "No. 9" which would take a 21-in.

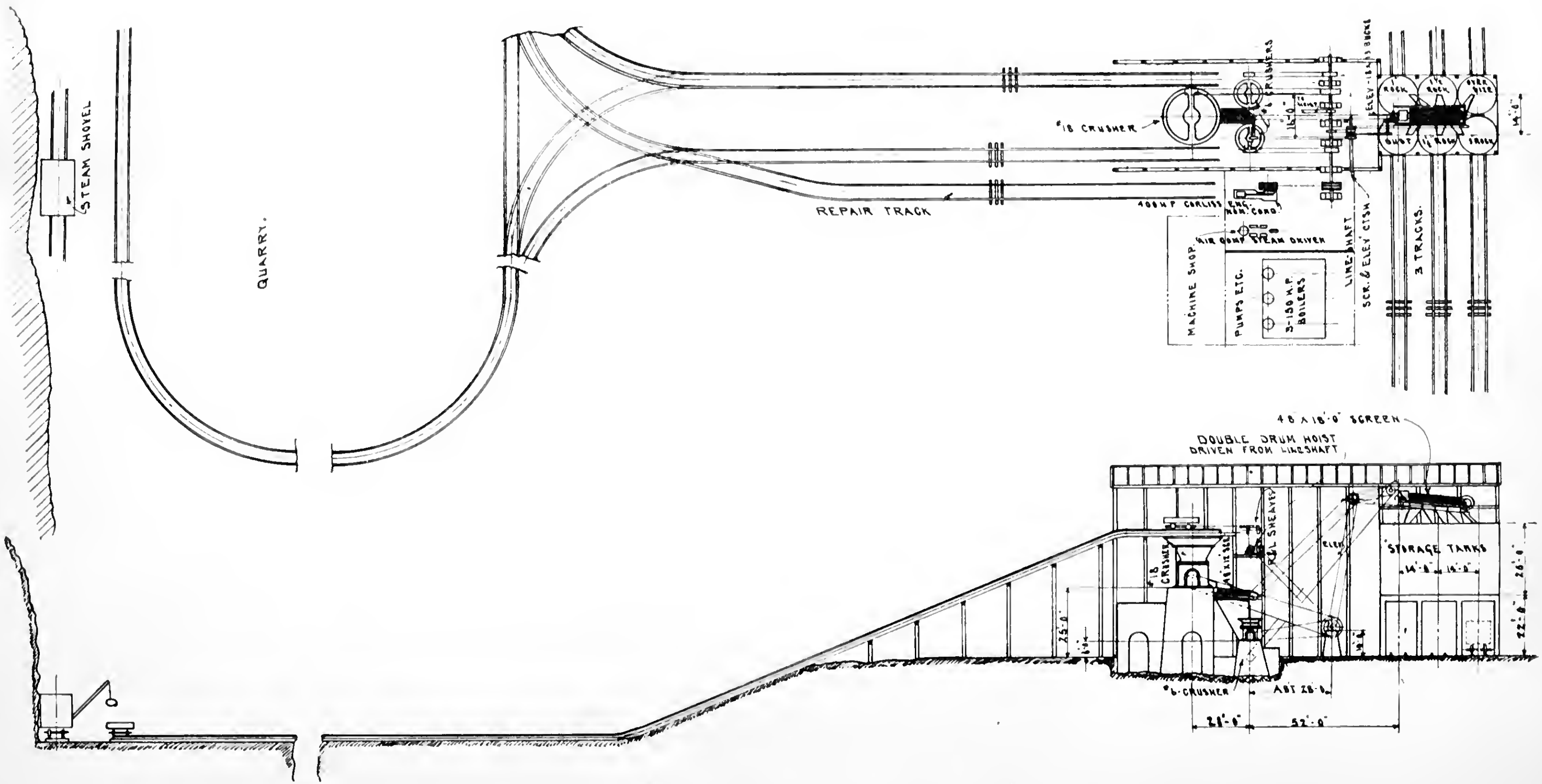



FIG. 3. PLAN AND ELEVATION OF CRUSHING PLANT WITH NO. 18 AND TWO NO. 6 CRUSHERS.

cube, and later a "No. 10" was brought forth which would admit a 24-in. cube. These were decided strides toward reducing the cost per ton; the saving not alone being confined to the decrease in labor of breaking the rock to the 24-in. size, but less explosives per ton was required than formerly, as it was not necessary to "shatter" the rock into such small pieces when blasting. It was also discovered that the larger crusher produced more tons per H. P. hour than the smaller size.

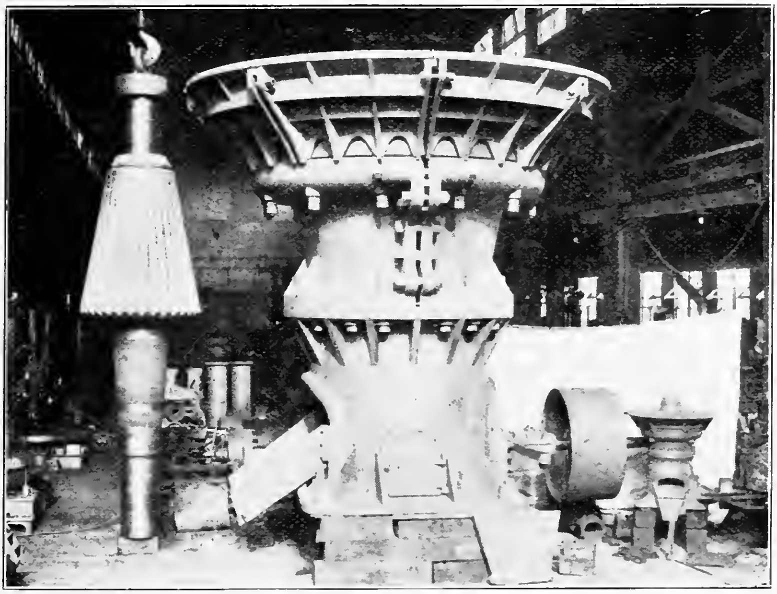
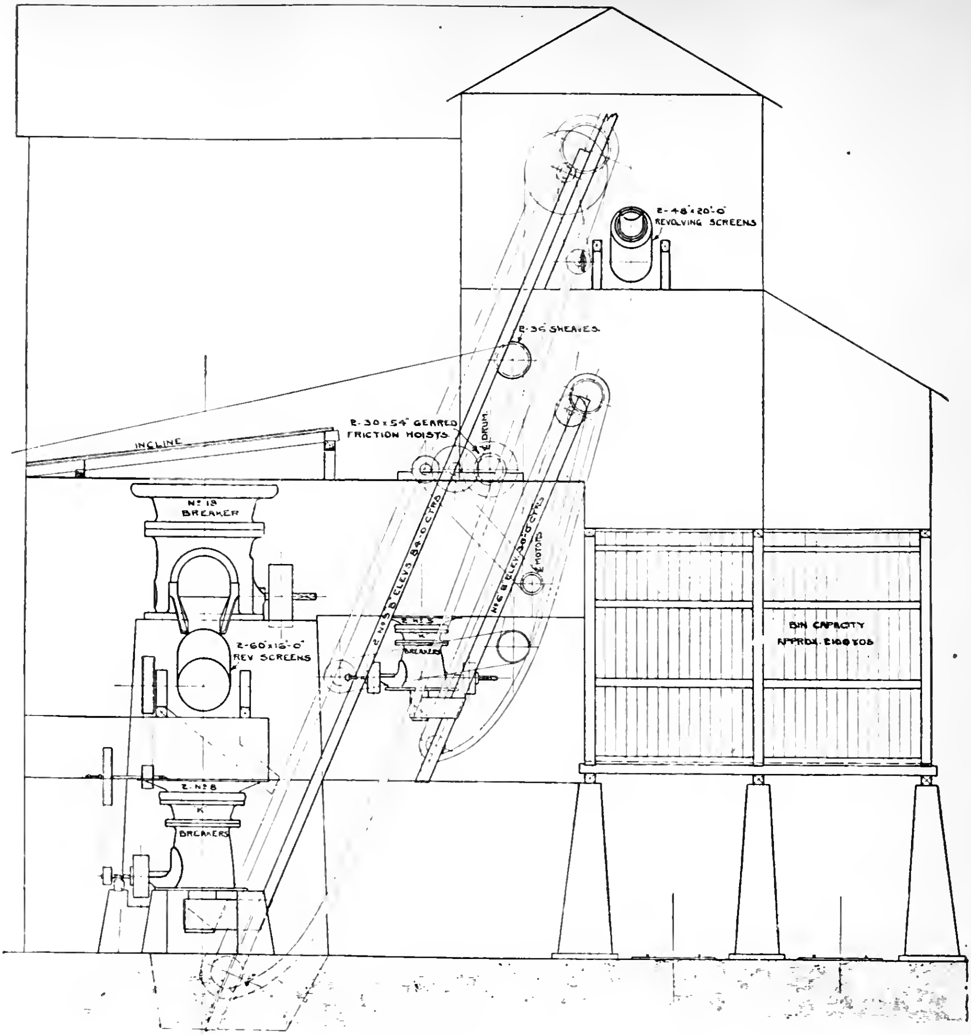


FIG. 5. NO. 18 BREAKER. SINGLE DISCHARGE TYPE.

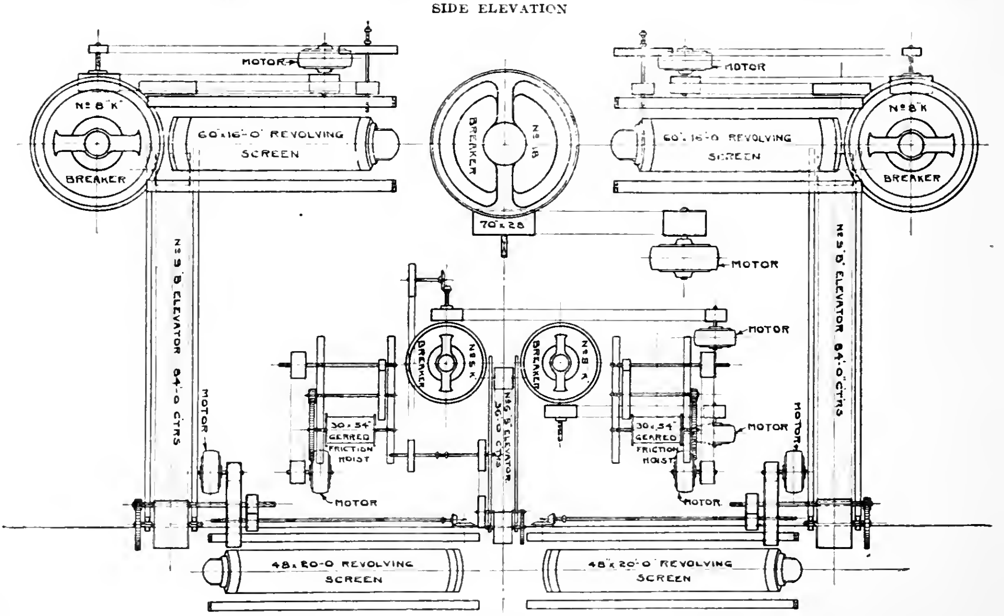
The H. P. curve of the different size crushers is shown in Fig. No. 2, based upon maximum cubes of rock they will receive.

These decided savings resulted in the building and installing of a giant or mammoth crusher (Number 18) more than double the weight of the largest crusher built at that time. These crushers were put into operation within the last year, and the results obtained have been more than satisfactory.

Fig. 3 shows an ideal lay-out for a 1,000-ton capacity plant and along the same lines as that shown in Fig. 1, but utilizing a No. 18 breaker and steam shovel for loading the rock in place of the No. 8 crusher and hand loading as shown in Fig. 1.



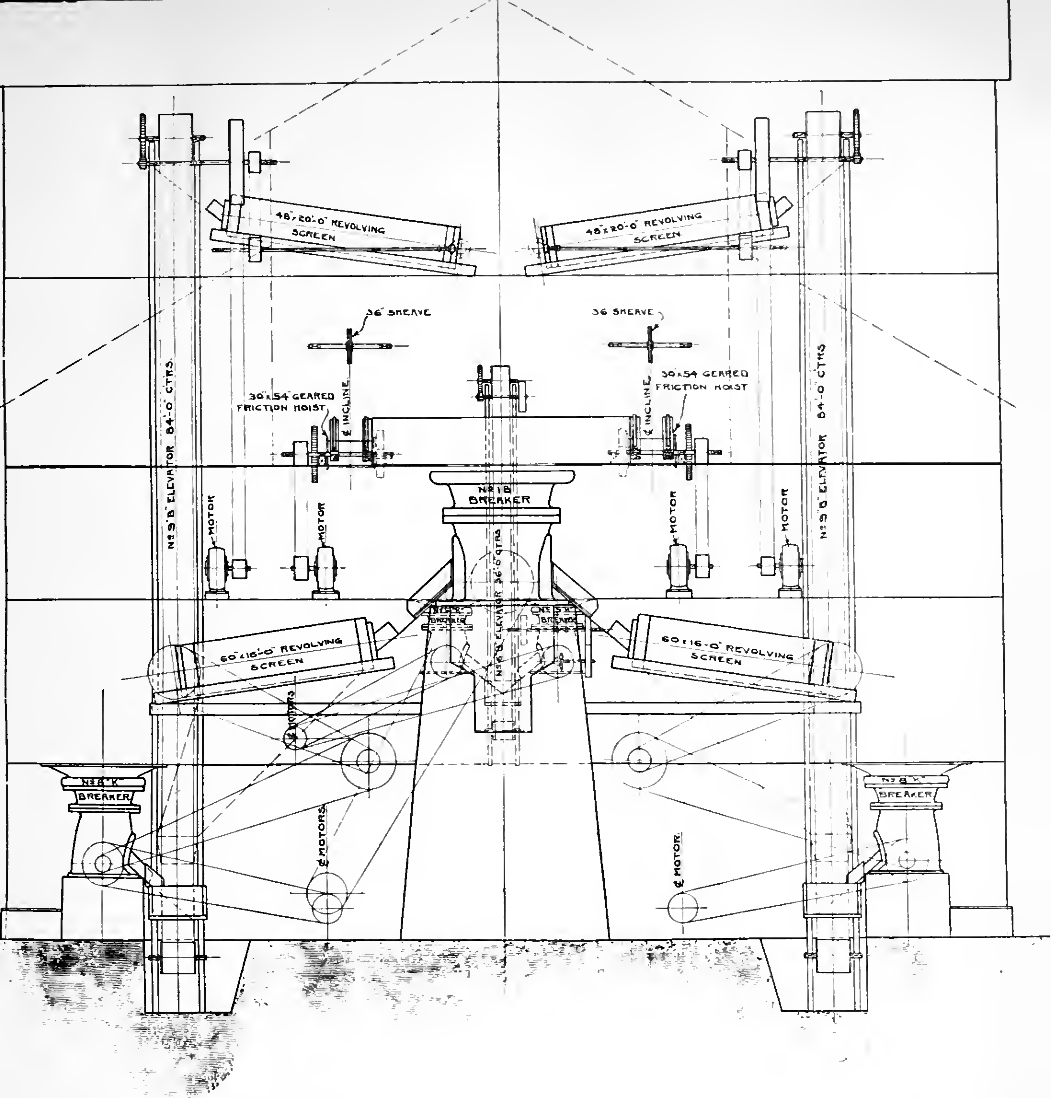

SIDE ELEVATION




PLAN (Bins omitted)

Crushing Plant Equipped with one No. 18, two No. 8 and two No. 5 Gates Gyratory Breakers.

FIG. 4.




End Elevation of Crushing Plant Equipped with one No. 18, two No. 8 and two No. 5 Gates Gyratory Breakers.

FIG. 4. (Continued.)

In comparing the installation costs of the arrangements as shown in Figures 1 and 3, it must be borne in mind that there is a limit to the capacity of the first plant; that is, a No. 8 crusher is easily capable of producing from 1,000 to 1,800 tons in ten hours, depending, of course, upon the fineness to which the rock is crushed, hardness, stratification, and size of rock delivered to it. However, it is assumed that the two plants are operating under exactly the same conditions and upon the same material. Due to the big difference in the cost of the large crusher, it is not advisable to install such a machine in plants of less than 1,000 tons capacity per day. But in the case of the No. 18 installation, the capacity of 1,000 tons can be increased eight times if desired with the addition of a relatively small percentage of power and small crushers as compared with the No. 8 installation. Increased storage being the same in both instances.

The following is the approximate cost of the installation shown in Fig. 1:

**Quarry Equipment.**

| | |
|---|---|
| 30 3-Ton Steel Cars (36-in. Gauge) | $ 3,000.00 |
| 140 Tons 40-lb. Rail with spurs, splices, etc., in place. (Trestle included.) | 4,000.00 |
| 3 Large Drills with rubber hose attachments, etc. | |
| 2 Air Hammers | 850.00 |
| 1 Steam Driven Air Compressor, installed complete with receiver, capacity 300 cu. ft., free air per min. | 1,350.00 |
| 1 Friction Hoist with 2,000 ft. ¾-in. cable installed with sheaves, idlers, etc., complete | 650.00 |

**Crushing Plant.**

**Buildings—**

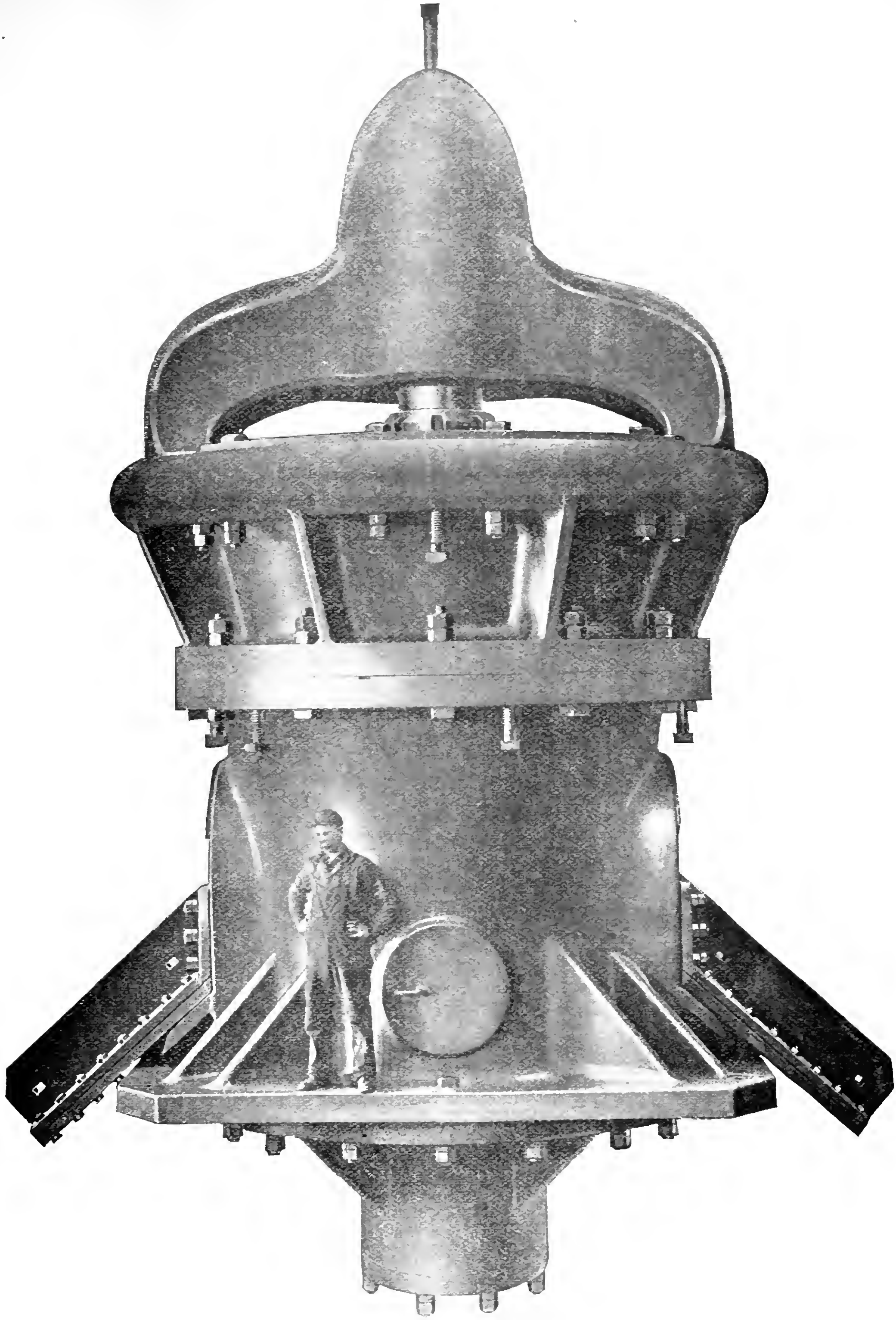
| | |
|---|---|
| (Wood-sides and roof covered with corrugated iron.) Including storage tanks, etc | 13,500.00 |

**Machinery—**

| | |
|---|---|
| 1 No. 8 Crusher installed | 5,200.00 |
| 2 No. 5 Crushers installed | 3,900.00 |
| 1 48-in.x12-ft. Screen installed | 900.00 |
| 1 18-in.x13-in. Continuous Bucket Elevator 78-ft. centers | 1,300.00 |
| 1 48-inx18-ft. Screen | 1,075.00 |

**Power Plant.**

| | |
|---|---|
| 1 250-H. P. Simple Corliss Engine installed | 2,500.00 |
| 3 100-H. P. Water Tube Boilers complete with heater, pumps, etc., in place | 6,300.00 |
| Lineshafting, Rope, Drives, Belting, etc., complete | 2,600.00 |



No. 18 Gates Rock and Ore Breaker.
FIG. 6.

| | |
|---|---|
| Machinery and Blacksmith Shop Equipment (including tool room containing sledges, hammers, wrenches, etc.) | 2,500.00 |
| Total Cost | $49,625.00 |

It is assumed that a face of not less than 20 to 25 feet can be secured for the steam shovel. Of course, the higher the face the less the shovel will have to move, and an appreciable reduction in the cost per ton is realized.

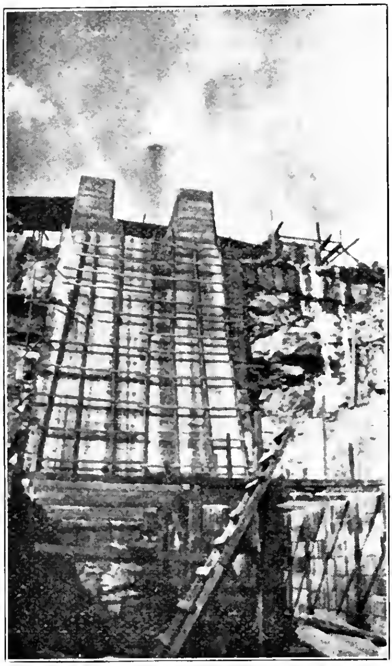


FIG. 7. CONCRETE FOUNDATION WITH FORMS STILL IN PLACE.

FIG. 8. CONCRETE FOUNDATION "STRIPPED."

The following is the cost of the installation shown in Fig. 3:

**Quarry Equipment.**

| | |
|---|---|
| 15 10-Ton Side Dump Cars (Std. Gauge) | $ 2,200.00 |
| 1 95-Ton Steam Shovel | 13,000.00 |
| 130 Tons 60-lb. Rail in place complete with splices, frogs, ties, etc | 5,600.00 |
| 3 Large Drills with rubber hose attachments, etc. 2 Air Hammers | 850.00 |
| 1 Dinky Locomotive for hauling cars | 2,600.00 |

### Crushing Plant.

| | |
|---|---|
| (Wood-sides and roof covered with corrugated iron), including storage tanks, etc. ........ | 15,000.00 |
| 1 No. 18 Crusher installed .................. | 24,000.00 |
| 2 No. 6 Crushers installed .................. | 5,200.00 |
| 1 48-inx12-ft. Screen installed ............... | 900.00 |
| 1 18-inx13-in. Continuous Bucket Elevator 78-ft. Centers ........................... | 1,300.00 |
| 1 48-inx18-ft. Screen ........................ | 1,075.00 |

### Power Plant.

| | |
|---|---|
| 1 400-H. P. Compound Engine .............. | 6,000.00 |
| 3 150-H. P. Water Tube Boilers, complete with heater, pumps, etc. ....................... | 9,450.00 |
| Lineshafting, Rope, Drivers, Belting, etc...... | 3,200.00 |

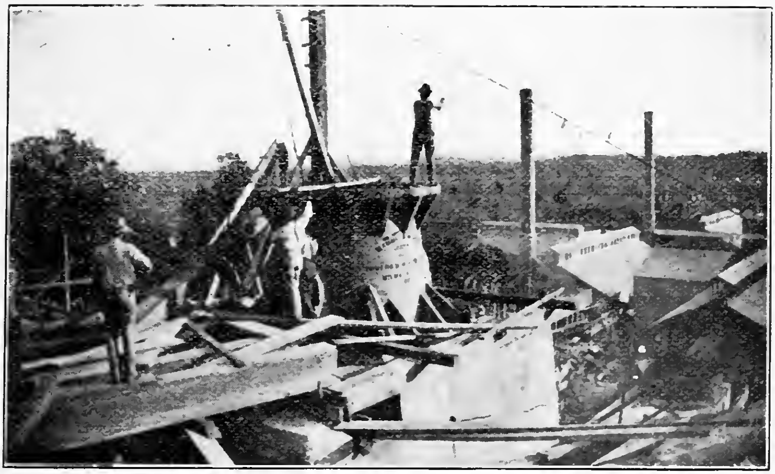


Fig. 9. View showing bottom shell in position. Weight 75,470 lbs.

| | |
|---|---|
| Machine and Blacksmith Shop Equipment, including tools, sledges, hammers, wrenches, etc. ................................ | 1,350.00 |
| Total Cost ........................ | $92,975.00 |

The following is the actual cost of operating a quarry and a crushing plant similar to the one shown in Fig. 1, common labor being $1.50 per day, powder $.115 per pound, power $0.004 per H. P. hour. The breaking and loading being done by contract, $0.30 per car or $0.075 per ton·

| | Cost Per Ton |
|---|---|
| **Drilling** | $0.03 |
| **Shooting** | |
| **Labor** | .007 |
| **Explosives** | .035 |
| **Breaking and Loading** (hand) | .105 |
| **General Expense** | .0165 |
| **Total for Quarrying** | $0.1935 |

FIG. 10. VIEW OF ONE-HALF OF UPPER SECTION BEING PUT IN PLACE.

| | |
|---|---|
| **Crushing** | .033 |
| **Transportation** | .043 |
| **Power** (250 H. P. at $0.004 per H. P. hr.) | .001 |
| **Total Cost delivered to bins** | $0.2705 |
| **Interest on Investment** ($50,000.00 at 6%) | .001 |
| **Depreciation, Renewals at 12%** | .002 |
| **Grand Total Cost delivered to bins** | $0.2735 |

The following is the cost of operating plant shown in Fig. 3:

| | |
|---|---|
| **Drilling** | $0.0275 |
| **Shooting** | |
| **Labor** | .006 |
| **Explosives** | .03 |

| | |
|---|---|
| **Loading** (Steam Shovel) | .05 |
| **General Expense** | .002 |
| **Total for Quarrying** | $0.1155 |
| **Crushing** | .025 |
| **Transportation** | .02 |
| **Power** (400 H. P. at $0.004 per H. P. hr.) | .0016 |
| **Total Cost delivered to bins** | $0.1621 |

FIG. 11. SCAFFOLDING FOR ERECTION OF BALANCE OF BREAKER.

| | |
|---|---|
| **Interest** at 6% on $93,000.00 | .0018 |
| **Depreciation, Renewals, etc** | .0036 |
| **Grand Total Cost delivered to bins** | $0.1675 |

Fig. 4 shows Plan and Elevations of one of the many arrangements possible with a "Double-Discharge" No. 18 Breaker.

In the above costs, repairs, supplies, etc., are all figured in, but do not include cost of stripping, as this varies considerably in different propositions. For an overburden from three to five feet deep, the cost of stripping per ton of rock produced is approximately $0.03. Comparing the above costs, it will be noticed that although the plant with the mammoth crusher and steam shovel costs, installed, nearly double the

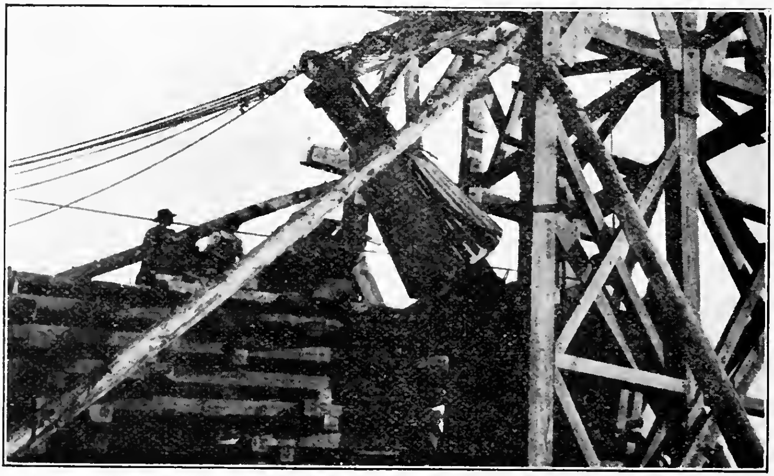


Fig. 12. Main Shaft with Breaking Head (Manganese Steel) Being Placed.

smaller plant, still the interest on this additional cost is negligible as compared with the saving effected by the use of the steam shovel and the labor saved in breaking up the rock to "one" and "two-man" size for the smaller crusher. In blasting, it is simply necessary in the case of the steam shovel to move it backward on its own track, "shoot off" the blast and the shovel is ready for work immediately. Whenever pieces of rock are too large for the "dipper," these are pushed aside and drilled with a small air hammer and broken up at noon or night as the case may be, it not being necessary on account of these small blasts to move the shovel. There are no "overhead" charges in the above costs, as these are too uncertain to attempt to estimate, but should not exceed, under ordinary conditions, over $0.03 to $0.08 per ton.

Fig. 5 is a general view of a No. 18 Breaker, "single-discharge" type with hopper. The main shaft with Breaking head is shown suspended to the left.

Fig. 6 is a general view of a No. 18 Breaker, "double-discharge" type without hopper.

The one shown in Fig. 6 has never been operated to capacity, and it is claimed by the manufacturers of the "double-discharge" type that the two discharges are necessary when producing over 3,000 tons per day of 10 hours.

Fig. 13. Crusher Erected.

The accompanying engravings. Figs. 7 to 16, are views showing the installation and erection of one of the No. 18 breakers. This breaker weighs 426,000 pounds. The main shaft with breaking head weighs 65,000 pounds. It is operated by a 300-H. P. motor, which also drives the screen 5 ft.x25 ft. for this crusher.

Fig. 17 shows a Power Curve for this crusher, the power necessary to crush each carload of rock is shown. The readings were taken from an ammeter located on the switchboard.

It will be noticed that the maximum power required or "peak load" occurs at the instant the load is discharged into the crusher, the power decreasing each revolution of the crusher shaft. In this particular installation, the crusher was

FIG. 14. SLOT IN QUARRY—SHOWING "DIPPER" OF SHOVEL AND ROCK DIRECT FROM BLAST READY FOR LOADING.

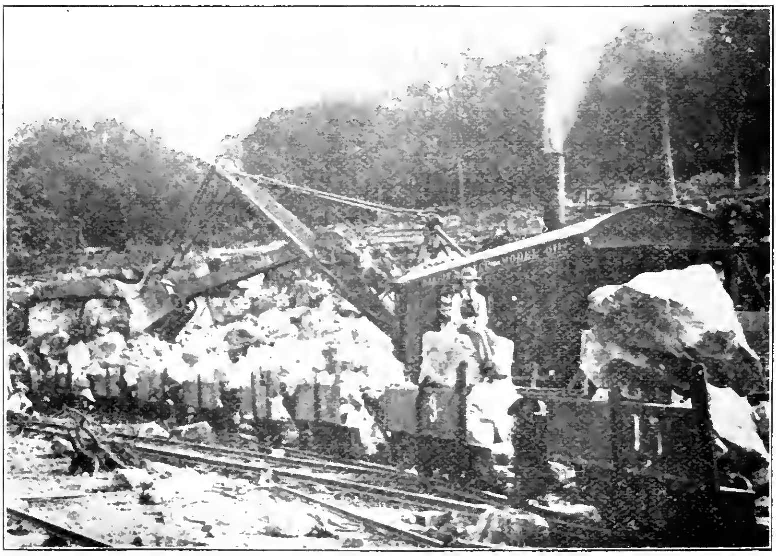
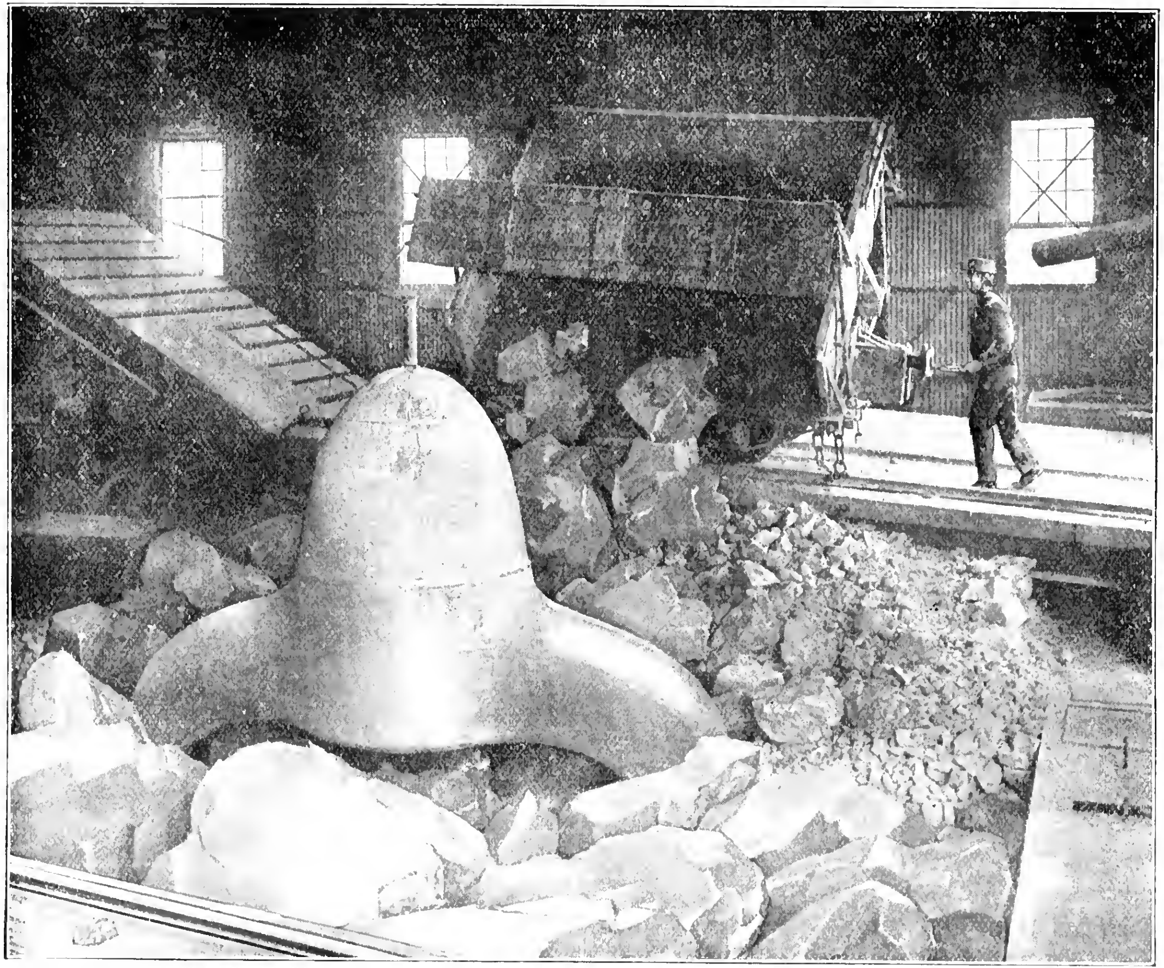


FIG. 15. TRAIN LOAD OF ROCK FOR CRUSHER. (THESE CARS WERE LATER REPLACED BY 6 YD. CARS.)



No. 18 Breaker—Two Arm Spider.

FIG. 16. CAR DISCHARGING INTO NO. 18 BREAKER.

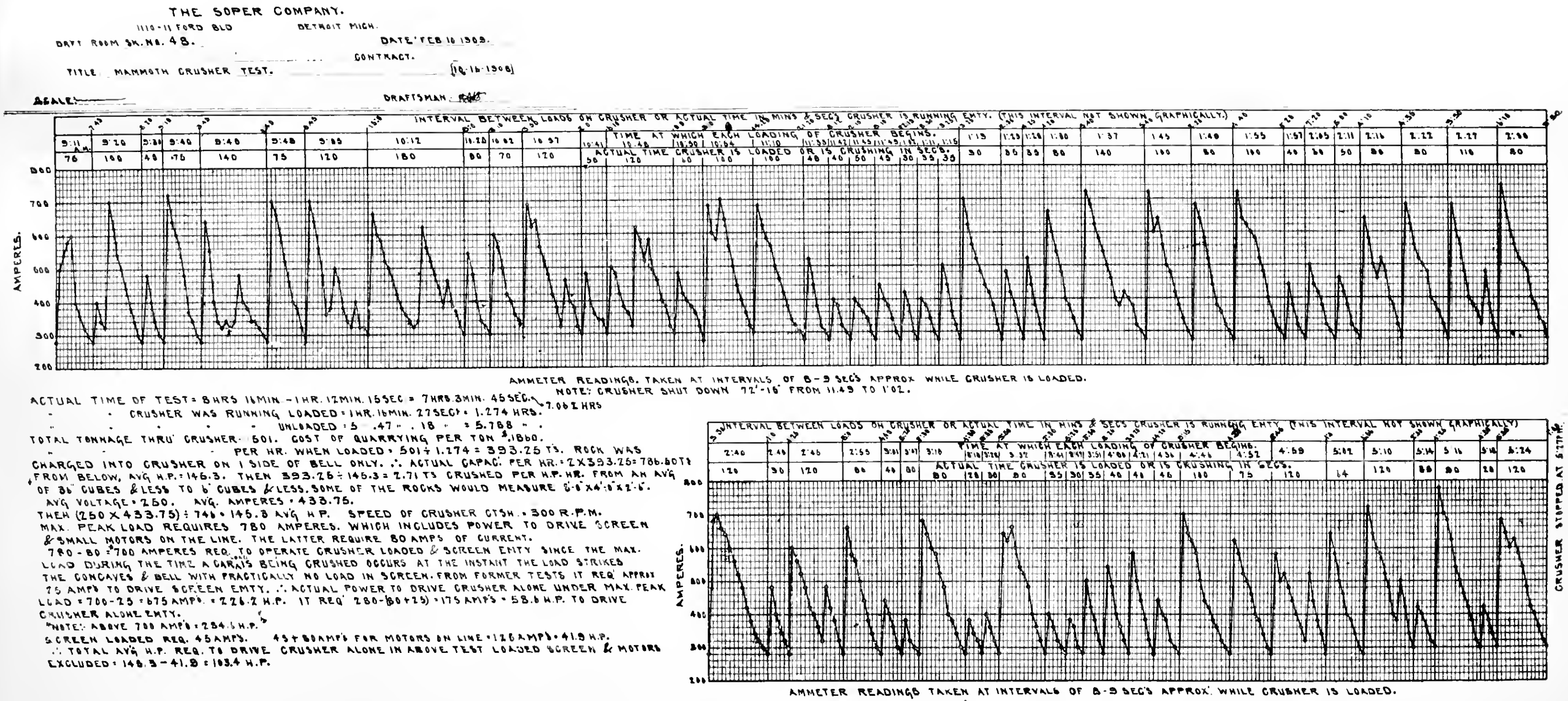



FIG. 17. POWER CURVE—No. 18 BREAKER.

installed to admit of the use of a large steam shovel for loading and handling the rock as it was not desired to operate the crusher to anywhere near its capacity. The intervals of time when the crusher was empty, that is, between loads, are not shown graphically. The actual time the crusher was loaded has been computed and the actual capacity of the crusher per hour found to be approximately 800 tons. The load shown graphically includes that required to drive the screen and several small motors on the line. Correcting the figures, it was

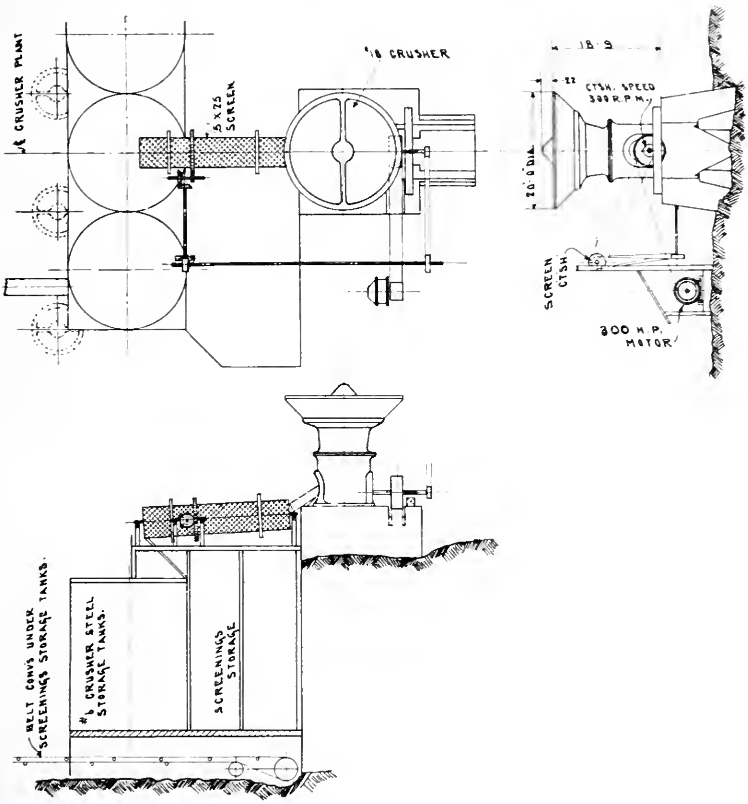



FIG. 18. GENERAL ARRANGEMENT OF NO. 18 CRUSHER AT THE DIXIE PORTLAND CEMENT PLANT.

found that it actually required to drive the crusher alone under maximum peak load 226 H. P. and approximately 58 H. P. to drive the crusher empty. Speed of the countershaft was 300 revolutions per minute. Average H. P. required to drive the crusher loaded, screen, etc., not included, was approximately 103 H. P.

The figure immediately at the top of each division, for instance 75—100—45, etc., represents the actual number of seconds required for the load to pass through the crusher. Wherever there is a break in the downward path of the curve, a small carload of rock was discharged into the crusher before the preceding load had passed through crusher. It will be noted that the average time for a single load to be crushed was 90 seconds, the loads averaging from seven to ten tons each. The crusher was set so as to crush to six inches and smaller.

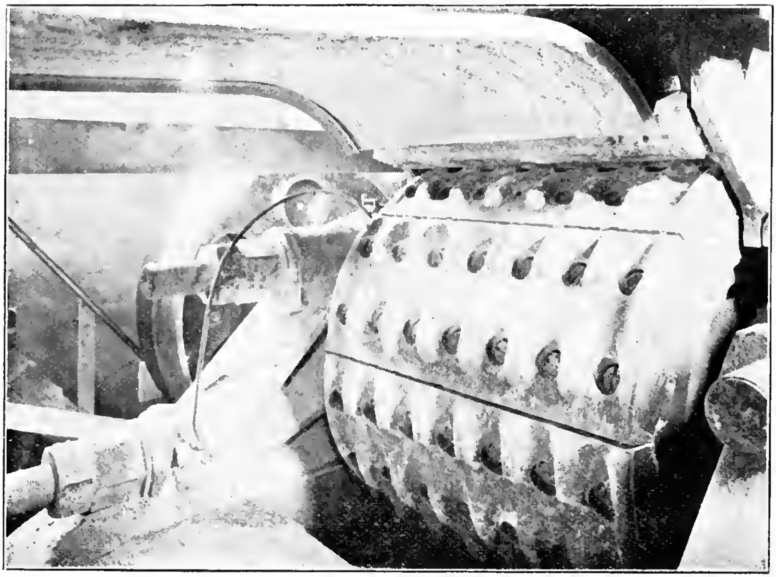


FIG. 19. VIEW OF EDISON GIANT ROLLS.

At the time this crusher was installed, it was not known what power would be necessary to operate it, and to be safe a 300 H. P. was installed, but a 200 or 225 H. P. motor would be ample.

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There have been several installations of Edison Giant or "inertia" rolls, which is a novel invention of Mr. Edison for crushing rock by the "inertia" of heavy revolving rolls. These rolls are about six feet in diameter with five feet face, steel chilled plates with projections for shattering up the rock. A general view of same is shown in Fig. 19. These rolls are capable of crushing a five or six-foot cube, and have a total capacity about equal or slightly greater than a No. 18 gyratory

breaker. Rolls of this size require at peak load approximately 450 H. P. and about 60 H. P. when operated empty. The rolls cost approximately $25,000.00 and a small royalty per ton of rock crushed is also required by the patentees.

The following are the actual costs of operating a No. 18 Breaker as compared with a Giant Roll:

**Comparison Operating Costs Per Ton.**

| **1,200-Ton Output** | Giant Edison Rolls. | No. 18 Gyratory Crusher. |
|---|---|---|
| Fineness crushed to | 10 in. | 6 in. |
| Labor | $0.0118 | $0.0044 |
| Oil and Waste | .0055 | .0004 |
| Repairs, Maintenance, etc. | .0020 | .0020 |
| Power | (250 H. P.) .0104 | (103 H. P.) .0043 |
| Total | $0.0297 | $0.0111 |

**Interest at 6% on Cost of Machines Installed Per Ton.**

| | | | |
|---|---|---|---|
| Edison Rolls | $30,000.00 | .005 | |
| Crusher | 24,000.00 | | .004 |

Note:—Power in both cases above figured at $0.005 per H. P. Hr.

Royalty on the Edison Rolls is not figured in the costs.

Depreciation is not over 6 to 8% and is assumed to be the same in each case. There is a slight difference in the total costs of machines installed in favor of the No. 18 Breaker.

Referring to this comparison it will be noted that it requires considerably more labor and power to operate the Rolls than the "Giant" Breaker.

# UNDERGROUND CONDUIT FOR THE DISTRIBUTION OF ELECTRICAL ENERGY.

BY W. F. SIMS.*

Corporations operating utilities which involve the distribution of electrical energy, have found it necessary in most cities to install a large number of their lines underground, either by reason of municipal requirements, or to secure greater safety of lines and reliability of service than can be obtained with overhead construction. The proper design and construction of a system of underground conduit for these lines is one of the problems which confronts the engineers who are responsible for the distribution system.

The requisites of a good conduit line are that the ducts shall be of a durable, incombustible, insulating substance with a high fusing point (thus being an arc resisting material); that cables may be readily installed or removed; that the cables when once installed are effectively protected from mechanical injury; and that they are thoroughly isolated from each other.

The results obtained from practical experience have demonstrated that vitrified clay is the material best suited for the manufacture of the ducts. This material is impervious to moisture, is a good insulator, and having a high fusing point is one of the best arc resisting materials available. Its comparatively low cost and practical indestructibility when in place have brought this material into almost universal use. The other forms of duct material used are wrought iron pipe, concrete ducts, cement lined iron pipes, and bitumenized fibre ducts. The last is a comparatively recent entry into the field, but gives promise of very good results when properly laid.

Vitrified clay ducts are made both in the single and multiple forms, as shown in Figs. 1 and 2 respectively. Multiple ducts are made in two, three, four, and six duct sections, the most common of which is the four duct section shown. The square bore single duct is better adapted for use on light and power lines than is the multiple form, as its use permits the breaking of joints between ducts and furthermore interposes two tile walls instead of one between adjacent rows. Where multiple duct sections are used, the joints rarely close, and in consequence openings are left between ducts which afford a ready means for the spread of trouble between cables in adjacent ducts. If the joints are properly broken in single duct construction, there is little danger of trouble spreading in this manner, and the structure is much stronger than is the case when joints are not broken.

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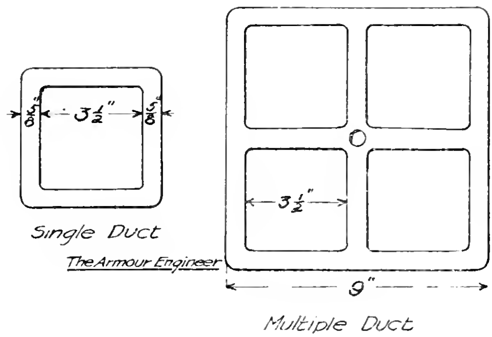
*Class 1897. Field Engineer, Division of Electrical Transmission and Distribution, The Board of Supervising Engineers, Chicago Traction.

The usual specifications for tile ducts provide that the material shall be of first quality, thoroughly vitrified clay, covered with salt glaze and free from cracks, blisters, splits, or other imperfections that would impair the are resisting qualities of the tile. The interior of the ducts should be smooth and free from any projections liable to injure the sheath of the cables when being drawn into place. All ducts should be straight and true, of the sizes specified, and all ends should be square. Many specifications provide for subjecting the tile to an absorption test, in which case the allowable absorption of water is from two to three per cent of the original weight of the duct.




FIGS. 1 AND 2. DUCT CROSS SECTIONS.

The design of an underground conduit system depends largely upon local conditions, and is also influenced by municipal regulations covering the extent of territory within which it is required that all conductors be carried underground. The number of cables required by the service to be given having been determined, it is necessary to select the routes along which they are to run. This selection is governed by several factors, the most important of which are the comparative lengths of the various routes, a proper consideration of the necessity for separate runs of cables to the same general locality, the underground conditions in the available streets, and other matters purely local, such as traffic, character of pavement etc. The number of ducts in each run is governed by the number of cables to be carried, coupled with a suitable allowance for the future growth of service requirements. The number of spare ducts allowed varies from ten to one hundred or more per cent of the immediate needs, but four ducts are usually the minimum in any one run.

In the design of a conduit system care should be taken to avoid large conduit sections for several important reasons. The presence of many cables in one run is objectionable owing to the difficulty of properly caring for the cables at the manholes, the danger of a shut down of a large part of the system in the event of trouble developing in one cable in a heavy line and spreading to adjacent cables, and also on account of the higher temperature of the cables in the larger groups. In small groups the radiation of heat is more rapid, owing to the relatively larger surface of the conduit exposed to the surrounding earth, and to the less number of intervening ducts. This rise in temperature tends to increase the resistance of the cables, and also the danger of burn outs.

In order to afford access to the cables, vaults or manholes must be provided at intervals along the conduit. Their location is dependant in a measure upon the nature of the business. If the system is being built for lighting or general power purposes a manhole should be built at each of the intersecting streets, in order that the systems may be readily extended in either direction along these streets at a minimum of expense. If it is for street railway service it is only necessary to consider the streets upon which there are intersecting car lines. On such systems it is also necessary to locate manholes wherever trolley taps are required. Additional manholes should be located at such intervals between those noted above that the weight of the cable to be installed will not be sufficient to cause injurious strains in the lead sheath or the insulation while the cable is being drawn into place. The present practice is to limit this interval to about four hundred and fifty to five hundred feet, although where the load to be carried is light and the cables of small diameter, spacings of five hundred and fifty feet are sometimes allowed. As it is often necessary to install additional manholes on account of obstructions in the street, or for other causes as noted above, the average distance between manholes on an entire system is usually about three hundred and fifty feet.

The general details of conduit construction must be decided in the field as the work progresses owing to the uncertainty of the conditions likely to be encountered. The most economical arrangement of ducts is with a cross section as nearly square as possible but the best practice is not to exceed four ducts in width, so that there will be no more than two cables in each layer on each side of the manhole. With this arrangement, it is possible to properly rack and protect the cables through the manholes, and at the same time the radiation of heat is facilitated. The ducts should be separated into two groups spaced horizontally about six or eight inches apart where they enter the manhole, in order that the spread of

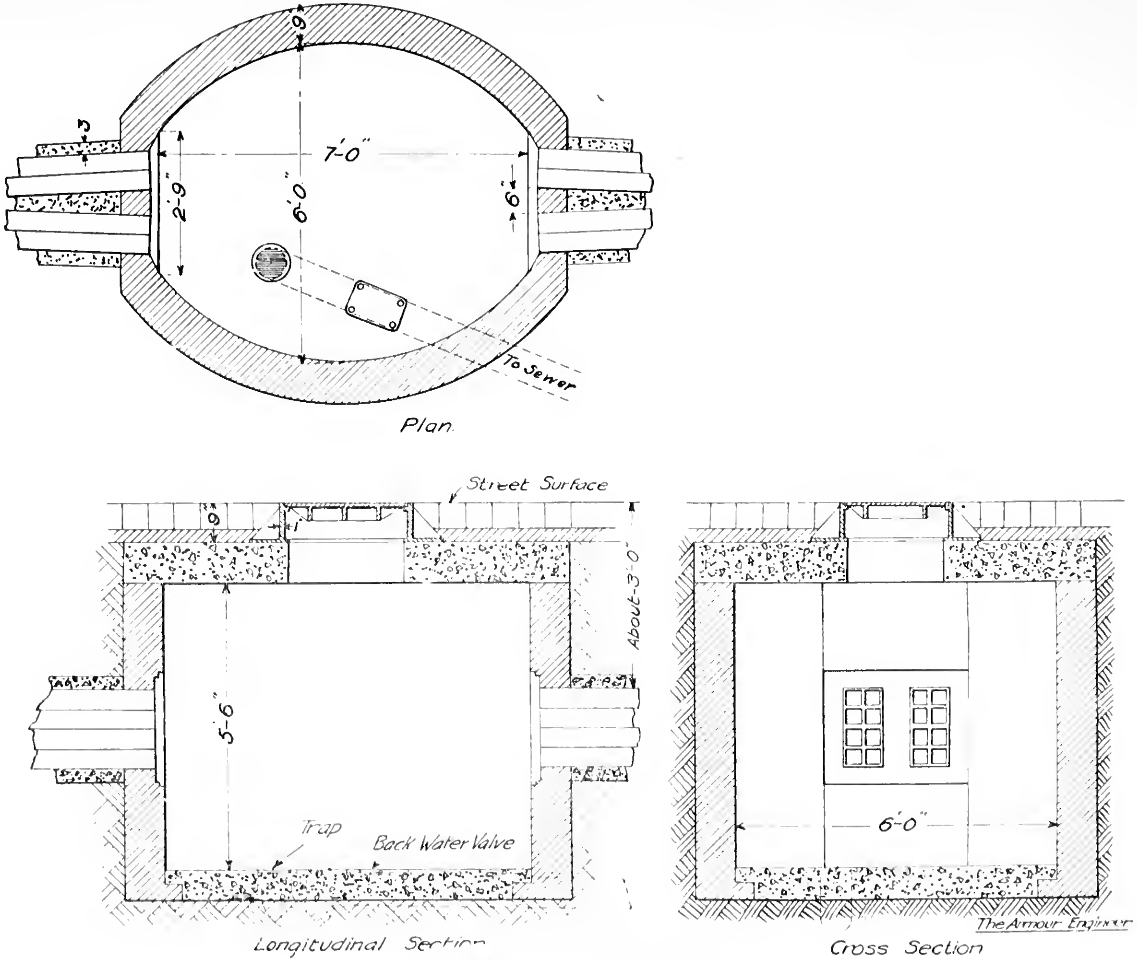



FIG. 3. STANDARD MANHOLE.

trouble between cables at this shall be reduced to a minimum. This separation is made by spreading the ducts, starting at a point about six feet away from the manhole. The space thus left between the groups should be filled with concrete. Fig. 3 shows this arrangement.

In locations where a separation of duct lines is desirable, but where the expense of independent runs is greater than is warranted by the advantages to be secured, the ducts may be laid in two groups separted by a wall of concrete from three to six inches in thickness. When such construction is adopted,

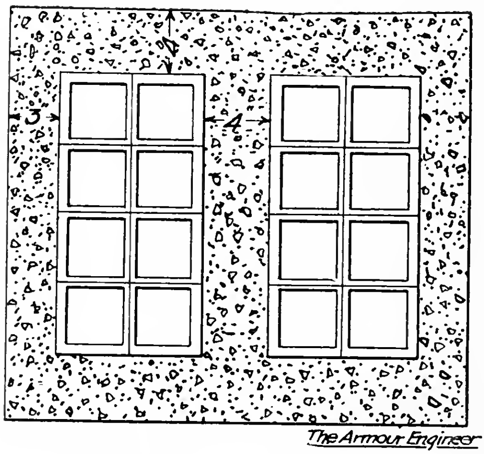



FIG. 4. SEPARATION OF RUNS BY CONCRETE BARRIER.

the separation at the manholes should be increased so that the barrier wall may be built between the groups, projecting into the manhole about sixteen inches. This arrangement is shown in Fig. 4.

The size of manholes depends largely upon the number of cables to be carried through and also upon the importance of the lines. The following tabulation shows the sizes in common use:

| Number of Ducts | Size of Manhole |
|---|---|
| 4 to 6 | 4 ft. x 5 ft. |
| 7 to 9 | 5 ft. x 6 ft. |
| 10 to 16 | 6 ft. x 7 ft. |
| over 16 | 7 ft. x 8 ft. |

Manholes should be of such shape that it is possible to install the cables in a safe manner without the necessity for sharp bends. Fig. 3 shows the standard design of manholes used by several large corporations operating underground lines. The exact size and shape of manholes as well as the arrangement and depth of the ducts is influenced by the number and position of other underground structures, such as gas and water mains, catch basins, and other conduit lines, but the standard dimensions and design should be followed as closely as is possible.

Manholes may be built either of brick or of concrete or of brick with a concrete roof. The concrete manhole is probably the least expensive form, but as it takes longer to build, the brick construction is generally used except where street traffic is light. Where brick roofs are used, they are supported by angle and T irons, or on large vaults by I beams between which brick arches are sprung. Access to manholes is obtained through openings in the roof closed by a removable cast iron cover set in suitable frames of the same material, and located over the center line of the ducts in order to facilitate the installation of cables. The cover and frame should be of such a design that they will safely support such loads as are incident to street traffic, and at the same time are of such weight as to be readily opened by one man. The cover should be so made that it cannot be jarred open by passing vehicles.

The cover should be provided with holes for the purpose of securing ventilation, as it is desirable to provide for the escape of such gases as may collect in the manhole, and also to assist in the carrying off of the heat generated in the cables. These holes should be of such size as not to catch the caulks of horses shoes and should be slightly larger at the bottom than at the top to prevent plugging up with dirt. The exposed surface of the cover should be checkered to prevent it from wearing smooth, and should have the name of the company owning the system in legible raised letters.

A common type of frame is the rectangular form, nine or ten inches high with a clear opening about twenty-four by twenty-eight inches. The cover rests upon a lip around the inside of the frame, and is provided with lugs on one side which hook under this lip and tend to prevent the cover from being jolted out of place. Such frames weigh from five hundred to six hundred pounds, and the covers about two hundred pounds.

Before beginning the construction of a conduit line it is necessary to obtain as much information as is possible regarding the number and location of pipes, conduits, catch basins, and sewers already in place. As there are usually no accurate records of the location of such structures, the desired informa-

tion is generally obtained by excavating test holes at intervals along the line of the proposed conduit and noting the location of the obstructions exposed. From the information thus obtained the most available location may be selected and the best arrangement of ducts decided. The trench should then be excavated to the width and depth required, and graded so as to drain to the manholes wherever possible. The depth should be such that the top of the upper tier of the ducts is about three feet below the street surface wherever the conditions permit. The lines and grade should be laid out so that the line is as straight as the obstructions in the street will allow, and that sharp bends and reverse curves are avoided.

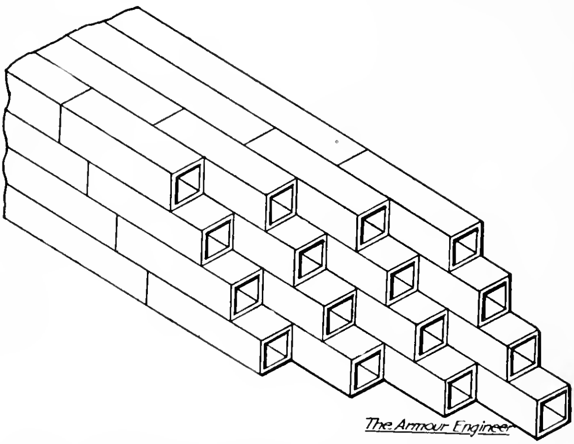



Fig. 5. Method of Laying Duct to Break Joints.

A foundation layer of concrete about three inches thick should be thoroughly tamped in the bottom of the trench and upon this the ducts laid.

The ducts should be laid upon wood mandrels about five feet long and about one-quarter of an inch smaller in each dimension than the interior of the duct. These mandrels should be provided with leather washers at the rear end closely fitting the ducts, and at the forward end with metal edges or loops by means of which the workmen may pull them through as the ducts are laid. The purpose of these mandrels is to insure proper alignment of the bore of the abutting ducts, and to prevent the accumulation of mortar and dirt in the interior. The number of mandrels in use should be frequently checked up in order that none may be left in the ducts.

The joints between adjacent ducts should be so located that in no case will the joint in one duct be opposite the joint in any adjacent duct. This may be accomplished by laying the horizontal layers with what is known as "half bond", and the vertical rows with "quarter bond", as shown in Fig. 5. The longitudinal joints between ducts should be thoroughly filled with cement mortar so as to reduce the danger of spreading of trouble between the cables in adjacent ducts, and for the same reason a coating of mortar should be spread over each layer of ducts. This part of the work is one that is usually slighted on account of the supposedly large increase in cost of duct laying, but in the opinion of many engineers the slight increase in cost actually entailed is more than justified in the greater protection afforded the cables, and by the reduction of expense due to burn outs.

As the additional cost due to this construction designed to more effectively protect the cables is at the most not greater than one cent per duct foot, and usually much less than that amount, and as the value of the cable in the duct is from fifty cents to a dollar per foot, and as a burn out may not only damage adjacent cables but may cause serious damage to the sub-station or power house apparatus, the small amount spent to prevent such trouble is not only justified but should be considered a necessity. When continuity of service is an important factor, no reasonable expense in increasing the safety of the cables placed in the conduit should be spared.

As each layer of ducts is laid, the space between the ducts and the side of the trench should be filled in with concrete. This concrete encasement should be about three inches in thickness. Care should be taken to keep this space free from dirt in order that there may be a good bond with the foundation concrete. Over the top row a layer of concrete three or four inches thick should be tamped into place. This concrete serves to protect the ducts and cables in them from injury whenever the street is opened up for other purposes.

After the concreting is finished the trench should be refilled and all surplus earth and debris removed. The back filling should be done in layers about six inches in thickness, each layer being thoroughly rammed. As this work is usualy done before the concrete has set, the ditch should never be puddled, not only on account of the danger of washing out the cement, but owing to the danger of sand and dirt being washed into the ducts. Back filling around manholes should be done as the walls are brought up, in order that no voids may be left behind which might be the cause of settlement of he pavement.

Concrete for conduit construction should be composed of one part of Portland cement, three parts of good torpedo sand or clean limestone screenings, and five parts of crushed limestone or gravel, of the size known as three quarters inch or less. Larger sizes should be avoided on account of the small mass of concrete used. The usual specifications for good concrete material should apply to this work. Mortar for duct laying should be one part cement and two parts sand. Brick for manholes should be first quality hard burned sewer brick.

After the conduit has been constructed, and before the permanent paving is done, each duct should have a cleaning mandrel drawn through it in order that it may be ascertained that the ducts are clean and in suitable condition for use. Fig. 6 shows a form of mandrel in common use. If the work is done by contract, the specifications should provide that the contract-

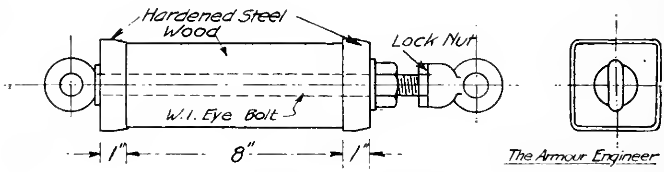



Fig. 6. Cleaning Mandrel.

or should draw the mandrel through the ducts in the presence of a representative of the company owning the line, and that the contractor shall rebuild at his own expense any part of the line through which the mandrel cannot be drawn. After any such repairs, the mandrel should again be drawn through all ducts in the section rebuilt.

The line for pulling the mandrel, and later the pull rope for the cable is drawn into the duct by means of jointed wooden rods which are usually in sections about three feet in length and care should be taken in manhole design to see that proper room is provided for handling these rods.

Previous reference has been made to bitumenized duct material. This is made in lengths of about five feet with socket joints. It should be laid with a space of from one inch to an inch and a half between the ducts, which should be entirely filled with concrete. Some of the advantages of this material are ease of handling on account of light weight, presentation of a nonabrasive surface to the lead sheath of the cable and the securing of a good alignment at the joints.

## TABLE I.

### Estimated Cost per Conduit Foot—Prices in Dollars

| | NUMBER OF DUCTS | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | 4 | 6 | 8 | 9 | 10 | 12 | 15 | 16 | 18 | 20 | 24 |
| Excavation* | .1443 | .1625 | .1800 | .1891 | .1931 | .2340 | .2275 | .2717 | .2944 | .2782 | .3172 |
| Concrete in Place | .2640 | .3120 | .3540 | .3600 | .3780 | .4140 | .4560 | .4680 | .5040 | .5160 | .5420 |
| Ducts,—At Trench | .2200 | .3300 | .4400 | .4950 | .5500 | .6600 | .8250 | .8800 | .3900 | 1.1000 | 1.3200 |
| Laying Ducts** | .0320 | .0480 | .0640 | .0720 | .0800 | .0960 | .1200 | .1280 | .1440 | .1600 | .1920 |
| Back Fill | .0152 | .0160 | .0166 | .0161 | .0165 | .0214 | .0173 | .0236 | .0254 | .0214 | .0242 |
| Repaving | .7500 | .7500 | .7500 | .8100 | .7500 | .9000 | .8100 | .9000 | .8100 | .9000 | .9000 |
| Total | 1.4255 | 1.6185 | 1.8046 | 1.9422 | 1.9676 | 2.3254 | 2.4558 | 2.6713 | 2.7678 | 2.9756 | 3.2954 |
| Total (excluding repaving) | .6755 | .8685 | 1.0546 | 1.1322 | 1.2176 | 1.4254 | 1.4458 | 1.7713 | 1.9578 | 2.0756 | 2.3954 |

### Estimated Cost per Duct Foot

| | NUMBER OF DUCTS | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | 4 | 6 | 8 | 9 | 10 | 12 | 15 | 16 | 18 | 20 | 24 |
| Excavation* | .0361 | .0271 | .0225 | .0210 | .0193 | .0195 | .0152 | .0169 | .0163 | .0139 | .0132 |
| Concrete in Place | .0660 | .0520 | .0442 | .0400 | .0378 | .0345 | .0304 | .0293 | .0280 | .0258 | .0226 |
| Ducts,—At Trench | .0550 | .0550 | .0550 | .0550 | .0550 | .0550 | .0550 | .0550 | .0550 | .0550 | .0550 |
| Laying Ducts** | .0080 | .0080 | .0080 | .0080 | .0080 | .0080 | .0080 | .0080 | .0080 | .0080 | .0080 |
| Back Fill | .0038 | .0026 | .0021 | .0018 | .0016 | .0018 | .0011 | .0015 | .0014 | .0011 | .0010 |
| Repaving | .1875 | .1250 | .0938 | .0900 | .0750 | .0750 | .0540 | .0562 | .0450 | .0450 | .0375 |
| Total | .3565 | .2697 | .2256 | .2158 | .1967 | .1938 | .1637 | .1669 | .1537 | .1488 | .1373 |
| Total (excluding repaving) | .1689 | .1447 | .1318 | .1258 | .1217 | .1188 | .1097 | .1107 | .1087 | .1038 | .0998 |

*Including Removing Debris.
**Including Mortar.

Where it is necessary to connect the underground cables to overhead lines, the cable is carried in a lateral duct running from a manhole to a bend at the base of the pole, and then in a riser up the pole. The most common form of lateral duct is of three inch wrought iron pipe connected to a length of pipe of the same diameter bent into a ninety degree bend to a thirty-six inch radius, the vertical end of the bend being set just above the ground level at the base of the pole and connected to a ver-

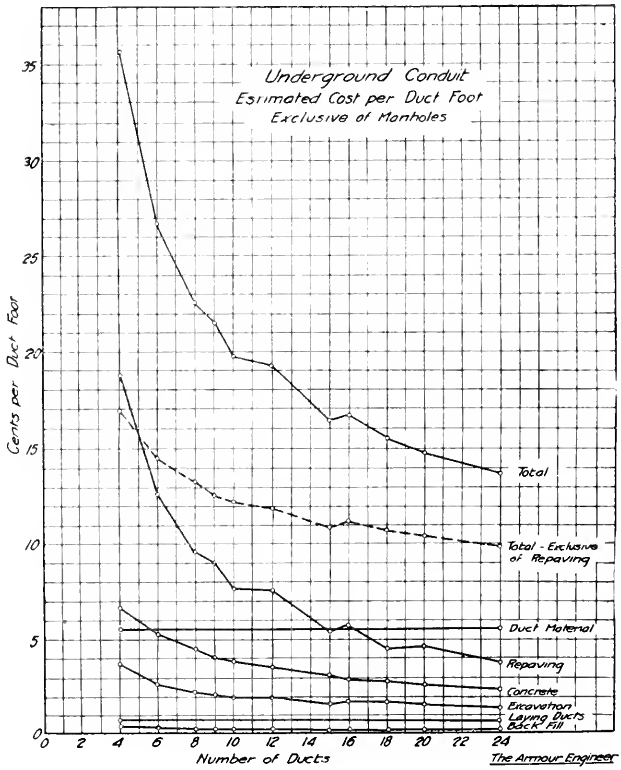



Fig. 7.

tical standpipe attached to the pole. In most cases that part of the pipe and bend below the surface of the ground are encased in concrete. This type of lateral is open to criticism on account of the fact that the lead sheath of the cable is grounded to the iron pipe and is liable to become damaged by electrolysis.

## TABLE II.

### Estimated Cost of Brick Manholes

| | SIZE OF MANHOLE | | | |
|---|---|---|---|---|
| | 4 ft.x5 ft. | 5 ft.x6 ft. | 6 ft.x7 ft. | 7 ft.x8 ft. |
| Excavation | $ 6.00 | $ 8.20 | $ 11.50 | $ 13.60 |
| Brickwork | 30.00 | 38.80 | 46.40 | 55.00 |
| Concrete | 2.50 | 3.40 | 4.60 | 6.20 |
| Steel | 9.25 | 10.60 | 18.00 | 22.50 |
| Cover and Frame | 14.50 | 14.50 | 14.50 | 14.50 |
| Sewer Connection | 21.00 | 21.00 | 21.00 | 21.00 |
| Repaving | 12.00 | 16.00 | 21.00 | 27.00 |
| Total | $95.25 | $112.50 | $137.00 | $159.80 |

A form of lateral duct has been proposed, made of fibre connected to a fibre duct bend, laid in concrete, and with the vertical standpipe protected by a wrought iron pipe of larger diameter. If properly installed, this form of lateral would insulate the lead sheath as effectively as in the case of the tile ducts, and would materially lessen the danger of trouble in such locations.

The cost of underground conduit construction varies between rather wide limits, due largely to local conditions, and is usually much higher in the business district than elsewhere. The number and location of underground structures, the nature of the soil, and the character of the pavement have a very marked effect upon the cost. Table 1 shows estimated costs based upon average conditions, and upon material and labor prices in a large city. The curves in Fig. 7 are plotted from the duct foot costs and show the various items of the work, the largest single factor on a section of less than fifteen ducts being the cost of repaving. The dotted line shows the cost of conduit per duct foot when no repaving is necessary. The cost of repaving is based upon prices prevailing in Chicago at the present time for repairing asphalt, granite block, brick, creosoted wood block pavement held under reserve. If the pavement is not under reserve or is of macadam, this cost will be about one half of the amount given.

Table II gives cost of brick manholes, and Fig. 8 shows cost per duct foot, assuming manholes to be of sizes specified on page 186, and spaced an average distance apart of 350 feet.

Under fair conditions, a good brick layer should lay about two thousand duct feet in eight hours, and two brick layers with three laborers should be able to build two manholes five feet by six feet in the same time.

One point to be constantly kept in mind in the construction of underground conduit is that it is being built for the sole purpose of providing a place in which to install cables, and therefore all work should be done in such manner as to secure the safest and most convenient place in which to do this. The manholes should be designed to provide ample space for hang-

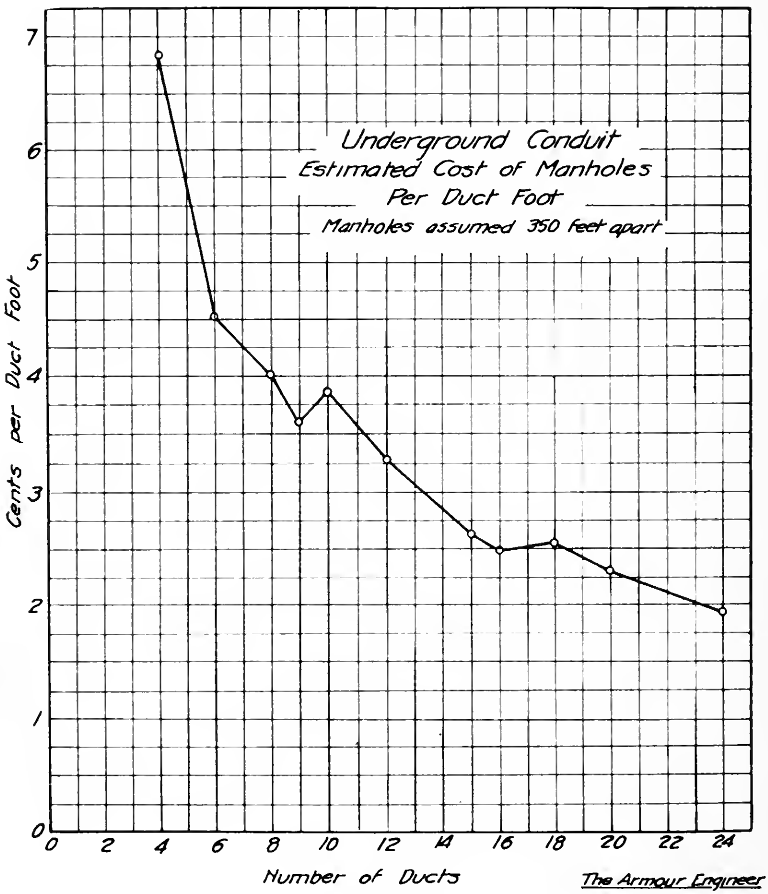



FIG. 8.

ing the cables in a neat and orderly manner, and to allow them to be covered with such protecting covering as may be necessary. When it is necessary to include gas or water mains in a manhole, additional space should be provided in order that there shall be sufficient room for the workmen when the cables

are jointed. Manhole covers should be placed so as to facilitate the work of cable installation, and when the manholes are unusually large, or are irregular in shape, more than one cover may be placed to advantage.

After an underground system has been installed, it should not be left to take care of itself, but should be frequently inspected and defects repaired as soon as noticed. Manholes should have mud and dirt, which have dropped through the holes in the cover, removed at regular intervals; and at the same time sewer connections and back water valves should be examined. Whenever openings are being made in the streets upon which a part of the system is located, an inspector should be detailed to see that no damage is done to the conduit or cables by such operations.

The cost of an underground system is very much greater than that of overhead systems of the same capacity, but on account of the lessened dangers of interruption of service and the lower maintenance charges, underground distribution is advisable wherever the additional investment can be justified.

# PROPERTIES OF SATURATED AND UNSATURATED AIR.

BY G. F. GEBHARDT.*

In dealing with the theory of cooling towers, evaporative surface condensers, and heating and ventilation, a thorough knowledge of the properties of saturated and unsaturated air is highly essential. Tables relating to the properties of saturated air may be found in most engineering handbooks and in many trade publications and little difficulty is experienced in applying them to existing engineering problems. But atmospheric air is never dry and is seldom saturated even during a severe thunder shower, hence a knowledge of the properties of unsaturated air is necessary for accurate analysis. In the average commercial problems there are so many indeterminable quantities on account of the variations in operation that the error due to the assumption that the air is either dry or completely saturated is entirely lost sight of in the liberal factors allowed for. In experimental investigations, however, conditions of operation may be maintained practically constant and the various influencing factors should be carefully considered.

Air is said to be saturated with water vapor when it contains the maximum amount possible at the existing temperature and pressure. If the air is only partially saturated the ratio of the mass of moisture present to the mass required for complete saturation at the given temperature is called the relative humidity. The latter, also, represents the ratio of the existing vapor tension to the maximum tension at the same temperature. The degree of saturation or relative humidity is ordinarily determined from the difference in reading of a wet and dry bulb thermometer, thus: If the air is saturated with aqueous vapor no evaporation takes place from the wet bulb and the two thermometers give identical readings; but if it be unsaturated, evaporation occurs, the wet bulb thermometer is thus cooled, and its reading is lower than that of the dry bulb. The difference in reading is a function of the relative humidity and the latter may be calculated from the following modifications of Apjohns' formula:

If the thermometer reads above 32° F.,

$$h = \left\{ P_w - \frac{dP}{88 x 30} \right\} \frac{100}{P_t} \qquad (1)$$

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If it reads below 32° F.,

$$h = \left\{ P_w - \frac{dP}{96 \times 30} \right\} \frac{100}{P_t} \qquad (2)$$

in which

$h$ = relative humidity, per cent.

$d$ = difference in reading of the wet and dry thermometers, degrees F.

$P$ = barometric pressure, inches of mercury.

$P_w$ = maximum tension of aqueous vapor corresponding to the temperature of the wet thermometer, inches of mercury. (This may be taken directly from the steam table.)

$P_t$ = maximum tension of aqueous vapor corresponding to the temperature of the dry thermometer, inches of mercury.

Example: Determine the relative humidity when the dry bulb reads 70° F., wet bulb 60° F., barometer 28.0.

From the steam tables we find

$P_w = 0.50$; $P_t = 0.73$

Whence

$$h = \left\{ 0.52 - \frac{10 \times 28}{88 \times 30} \right\} \frac{100}{0.73} = 55 \text{ per cent}$$

Tables giving the relative humidity in terms of the temperature difference are published in most engineering handbooks and the above calculations are unnecessary. These tables, however, are based on a fixed barometer pressure, whereas the formula takes the actual pressure into consideration.

The properties of saturated and unsaturated vapors are based on the following fundamental physical laws:

**Dalton's laws:**

(a) The mass of a given kind of vapor required just to saturate a given space at a given temperature is the same whether the vapor be all by itself or associated with vaporless gases.

(b) The maximum tension of a given kind of vapor at a given temperature is the same whether it is all by itself or associated with vaporless gases.

(c) In a mixture of gas and vapor the total pressure is equal to the sum of the partial pressures.

**Charles' laws:**

> All gases expand equally when heated at constant pressure and for every degree of Fahrenheit the amount of expansion is 1/460 of the volume occupied at 0° F.

For unsaturated water vapor the law is approximately true, the deviation being greatest as the saturation point is approached.

For saturated water vapor the law is not applicable and recourse must be had to Steam Tables.

**Boyle's laws:**

> The volume occupied by a given mass of gas under different pressures is inversely proportional to the pressure provided the temperature remains constant.

For unsaturated water vapor the law is approximately true, the deviation increasing as the saturation point is reached.

The error is negligible for most purposes.

For saturated water vapor the law is not applicable, and recourse must be had to Steam Tables.

These laws may be expressed:

**Dalton's law:**

For saturated air

$$P = P_a + P_v \tag{3}$$

For unsaturated air

$$P = P_a + hP_v \tag{4}$$

in which

$P$ = observed atmospheric pressure as obtained from the barometer.

$P_a$ = pressure of the dry air in the mixture.

$P_v$ = pressure of the vapor in the mixture. This may be taken directly from the Steam Tables. It is the pressure of the steam at the temperature corresponding to that of the mixture of air and vapor.

$h$ = relative humidity as determined from the wet and dry thermometer.

If $d$ = density or weight per cubic foot of a mixture of air and vapor at a given temperature,

$d_a$ = density of dry air at pressure $p_a$ and the given temperature.

and $d_v$ = density of vapor at pressure $p_v$ and the given temperature. (This may be taken directly from the Steam Table.)

Then,

For saturated air,

$$d = d_a + d_v \tag{5}$$

For unsaturated air,

$$d = d_a + hd_v \tag{6}$$

**Charles' law:**

$$v_1 = v \times \frac{t_1 + 460}{t + 460} \tag{7}$$

$$d_1 = d \times \frac{t + 460}{t_1 + 460} \tag{8}$$

in which

$v_1$ = volume of gas at temperature $t_1$ and pressure p.
$v$ = volume of gas at temperature $t$ and pressure p.
$d_1$ = density of gas at temperature $t_1$ and pressure p.
$d$ = density of gas at temperature $t$ and pressure p.

**Boyle's law:**

$$pv = p_1 v_1$$

$$pd_1 = p_1 d \tag{9}$$

**Laws of Charles and Boyle combined:**

$$V = V_1 \frac{P_1(t + 460)}{P(t_1 + 460)} \tag{10}$$

$$d = d_1 \frac{P(t_1 + 460)}{P_1(t + 460)} \tag{11}$$

We are now prepared to compute the various items in Table 1:

The standard atmospheric pressure is taken as 29.921 inches of mercury or 14.7 pounds per square inch, and all steam and air tables are based upon it. We will assume that steam tables are available and that density of dry air at 0° F. and pressure 29.921 is known.

Let us determine the various properties corresponding to, say, a temperature of 80° F.

Now the density of one cubic foot of dry air at 29.921 and 0° F. = 0.0864 pounds.

**Column 2.**

From equation (8)

$$d_1 = 0.0864 \frac{0 + 460}{80 + 460} = 0.07362;$$

density of one cubic foot of dry air at temperature 80° F. and pressure 29.921.

The various items in Table I, Column 2, have been multiplied by 1000 to avoid unwieldy decimals.

### Column 3.

The figures in the column are the reciprocal of the density of one cubic foot at the given temperature; thus for 80° F.

$$v = \frac{1}{0.0736} = 13.58$$

### Column 4.

From the Steam Tables we find the pressure of the vapor corresponding to a temperature of 80° F. to be 1.023 inches of mercury.

### Column 5.

From equation (3)

$29.921 = 1.023$

$P_a = 28.898$ inches of mercury, tension or elastic forces of the dry air in the mixture.

### Column 6.

Substitute $d_1 = 0.07362$ (as obtained in column 3), $P_1 = 28.898$ and $p = 29.921$ in equation (9),

whence

$29.921\ d_a = 28.898 \times 0.07362$

and $d_a = 0.0711$, weight of dry air in one cubic foot of mixture.

### Column 7.

From the Steam Tables we find the density of one cubic foot of vapor at 80° F. and pressure $p_v$ to be

$d_v = 0.00155$ lbs.

### Column 8.

From equation (5)

$d = d_v + d_a$

$= 0.00155 + 0.0711$

$= 0.07265$, total weight of one cubic foot of mixture.

### Column 9.

Ratio of water vapor to dry air in one cubic foot of mixture

$$\frac{d_1}{d_a} = \frac{0.00155}{0.0711} = 0.00218$$

**Column 10.**

Ratio of dry air to water vapor in one cubic foot of mixture

$$\frac{d_a}{d_v} = \frac{0.0711}{0.00155} = 46.0$$

**Column 11.**

Cubic feet of water vapor from one pound of water at pressure in column 4,

$$\frac{1}{d_v} = \frac{1}{0.00155} = 645$$

**Column 12.**

One cubic foot of dry air at 80° F. and pressure 29.921 weighs .07362 lbs. (Column 3).

0.07362 × 0.2375 = (specific heat of dry air) = 0.01748 B.T.U. necessary to heat one cubic foot of dry air one degree F.

**Column 13.**

One cubic foot of mixture at 80° F., contains 0.0711 lbs. dry air (column 6).

0.0711 × 0.2375 = 0.01688 B. T. U. necessary to heat dry air one degree F.

One cubic foot of vapor at 80° F. weighs 0.00155 lbs. (column 7).

0.00155 × 0.5 = (mean specific heat of water vapor*) = 0.000775 B. T. U. necessary to superheat vapor content one degree F.

0.01688 + 0.000775 = 0.01765 B. T. U., heat absorbed by one cubic foot of saturated air per degree F.

**Column 14.**

Cubic feet of dry air warmed one degree per B. T. U. = reciprocal of column 12.

$$\frac{1}{0.01748} = 57.21$$

**Column 15.**

Cubic foot of saturated air is warmed one degree B. T. U. = reciprocal of column 13.

$$\frac{1}{0.01765} = 56.65$$

*The mean specific heat varies from 0.6 for a superheat of one degree to 0.48 for a superheat of 150 degrees. The average is not far from 0.5 for the conditions of average practice.

Barometer

| Temperature Degrees F | Weight of 1000 Cubic Feet of Dry Air. Pounds. | Volume of One Pound of Dry Air Cubic Feet. | Elastic Force of Vapor in inches of Mercury (Peabody) | Mixture of Air Saturated: Elastic Force of Dry Air in the Mixture. Inches of Mercury. | Mixture of Air Saturated: Weight of 1000 Cu. ft. Pounds: Weight of the Dry Air. | Weight of the Vapor. | Total weight of the Mixture. |
|---|---|---|---|---|---|---|---|
| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
| 0 | 86.40 | 11.57 | 0.044 | 29.88 | 86.30 | 0.081 | 86.38 |
| 10 | 84.56 | 11.82 | 0.069 | 29.85 | 84.40 | 0.125 | 84.52 |
| 20 | 82.81 | 12.07 | 0.107 | 29.81 | 82.54 | 0.189 | 82.73 |
| 30 | 81.10 | 12.33 | 0.156 | 29.76 | 80.70 | 0.273 | 80.97 |
| 32 | 80.78 | 12.39 | 0.181 | 29.74 | 80.28 | 0.294 | 80.58 |
| 40 | 79.49 | 12.57 | 0.247 | 29.67 | 78.83 | 0.398 | 79.23 |
| 45 | 78.70 | 12.70 | 0.299 | 29.62 | 77.91 | 0.478 | 78.39 |
| 50 | 77.93 | 12.83 | 0.361 | 29.56 | 77.00 | 0.572 | 77.57 |
| 55 | 77.16 | 12.96 | 0.433 | 29.49 | 76.06 | 0.681 | 76.74 |
| 60 | 76.42 | 13.08 | 0.518 | 29.40 | 75.09 | 0.808 | 75.90 |
| 62 | 76.13 | 13.14 | 0.556 | 29.36 | 74.71 | 0.865 | 75.57 |
| 65 | 75.70 | 13.21 | 0.617 | 29.30 | 74.13 | 0.956 | 75.08 |
| 70 | 75.00 | 13.33 | 0.733 | 29.19 | 73.16 | 1.128 | 74.29 |
| 72 | 74.70 | 13.38 | 0.784 | 29.14 | 72.74 | 1.203 | 73.94 |
| 75 | 74.30 | 13.42 | 0.867 | 29.05 | 72.13 | 1.325 | 73.45 |
| 80 | 73.62 | 13.58 | 1.023 | 28.90 | 71.11 | 1.550 | 72.65 |
| 85 | 72.80 | 13.73 | 1.202 | 28.72 | 69.90 | 1.808 | 71.71 |
| 90 | 72.20 | 13.85 | 1.409 | 28.51 | 68.80 | 2.103 | 70.90 |
| 95 | 71.55 | 13.99 | 1.647 | 28.27 | 67.60 | 2.438 | 70.04 |
| 100 | 71.00 | 14.08 | 1.917 | 28.00 | 66.47 | 2.818 | 69.29 |
| 105 | 70.34 | 14.25 | 2.226 | 27.70 | 65.02 | 3.247 | 68.47 |
| 110 | 69.58 | 14.36 | 2.576 | 27.34 | 63.58 | 3.723 | 67.32 |
| 115 | 69.15 | 14.46 | 2.975 | 26.95 | 62.30 | 4.273 | 66.58 |
| 120 | 68.55 | 14.58 | 3.425 | 26.50 | 60.70 | 4.888 | 65.59 |
| 125 | 67.97 | 14.71 | 3.932 | 25.99 | 59.06 | 5.56 | 64.62 |
| 130 | 67.36 | 14.84 | 4.502 | 25.42 | 57.22 | 6.32 | 63.54 |
| 135 | 66.79 | 14.97 | 5.141 | 24.78 | 55.31 | 7.16 | 62.47 |
| 140 | 66.24 | 15.09 | 5.858 | 24.06 | 53.27 | 8.10 | 61.37 |
| 145 | 65.69 | 15.22 | 6.65 | 23.27 | 51.10 | 9.14 | 60.24 |
| 150 | 65.15 | 15.34 | 7.54 | 22.37 | 48.72 | 10.28 | 59.06 |
| 155 | 64.73 | 15.45 | 8.53 | 21.39 | 46.28 | 11.55 | 57.82 |
| 160 | 64.16 | 15.58 | 9.63 | 20.29 | 43.48 | 12.93 | 56.41 |
| 165 | 63.59 | 15.72 | 10.83 | 19.09 | 40.60 | 14.46 | 55.06 |
| 170 | 63.16 | 15.83 | 12.17 | 17.75 | 37.46 | 16.13 | 53.59 |
| 175 | 62.56 | 15.99 | 13.64 | 16.27 | 34.03 | 17.95 | 51.98 |
| 180 | 62.09 | 16.10 | 15.27 | 14.65 | 30.41 | 19.94 | 50.35 |
| 185 | 61.61 | 16.23 | 17.04 | 12.88 | 26.54 | 22.12 | 48.66 |
| 190 | 61.14 | 16.36 | 18.98 | 10.94 | 22.19 | 24.49 | 46.68 |
| 195 | 60.68 | 16.50 | 21.12 | 8.80 | 17.89 | 27.08 | 44.97 |
| 200 | 60.22 | 16.61 | 23.44 | 6.48 | 13.08 | 29.87 | 43.95 |
| 205 | 59.80 | 16.72 | 25.99 | 3.93 | 7.85 | 32.90 | 40.75 |
| 210 | 59.30 | 16.86 | 28.74 | 1.18 | 2.34 | 36.20 | 38.54 |
| 212 | 59.10 | 16.92 | 29.92 | 0 | 0 | 37.51 | 37.51 |

## SATURATED AIR

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| With Vapor. Ratio of Water Vapor to Dry Air. | Ratio of Dry Air to Water Vapor. | Cubic Feet of Vapor from one pound of Water at Pressure as in Column 4 | B. T. U. Absorbed by 1000 Cubic feet of Dry Air Per Degree F. | B. T. U. Absorbed by 1000 Cubic feet of Saturated Air Per Degree F. | Cubic Feet of Dry Air Warmed one Degree F. per B. T. U. | Cubic Feet of Saturated Air Warmed one Degree Per B. T. U. | Temperature Degrees F. |
|---|---|---|---|---|---|---|---|
| 9 | 10 | 11 | 12 | 13 | 14 | 15 | 1 |
| 0.00093 | 1072 | —— | 20.56 | 20.52 | 48.63 | 48.58 | 0 |
| 0.00147 | 677 | —— | 20.12 | 20.15 | 49.68 | 49.63 | 10 |
| 0.00228 | 437 | —— | 19.71 | 19.74 | 50.74 | 50.65 | 20 |
| 0.00338 | 295 | —— | 19.30 | 19.34 | 51.81 | 51.70 | 30 |
| 0.00367 | 272 | 3395 | 19.22 | 19.25 | 52.02 | 51.93 | 32 |
| 0.00505 | 198 | 2512 | 18.92 | 18.96 | 52.86 | 52.74 | 40 |
| 0.00613 | 163 | 2092 | 18.73 | 18.78 | 53.38 | 53.25 | 45 |
| 0.00744 | 134 | 1749 | 18.54 | 18.61 | 53.91 | 53.73 | 50 |
| 0.00895 | 111 | 1468 | 18.36 | 18.44 | 54.40 | 54.23 | 55 |
| 0.01076 | 93 | 1237 | 18.18 | 18.27 | 54.96 | 54.73 | 60 |
| 0.01158 | 86 | 1156 | 18.11 | 18.20 | 55.06 | 54.94 | 62 |
| 0.01290 | 78 | 1044 | 18.01 | 18.12 | 55.52 | 55.19 | 65 |
| 0.01520 | 65 | 887 | 17.85 | 17.97 | 56.00 | 55.64 | 70 |
| 0.01650 | 60 | 831 | 17.78 | 17.93 | 56.30 | 55.77 | 72 |
| 0.01860 | 55 | 755 | 17.58 | 17.86 | 56.80 | 55.99 | 75 |
| 0.02180 | 46 | 645 | 17.48 | 17.65 | 57.21 | 56.65 | 80 |
| 0.02580 | 39 | 553 | 17.30 | 17.50 | 57.80 | 57.14 | 85 |
| 0.03050 | 33 | 475 | 17.10 | 17.39 | 58.48 | 57.50 | 90 |
| 0.03600 | 28 | 410 | 17.00 | 17.27 | 58.82 | 57.90 | 95 |
| 0.04240 | 24 | 354 | 16.89 | 17.20 | 59.20 | 58.14 | 100 |
| 0.04980 | 20 | 308 | 16.74 | 17.09 | 59.74 | 58.50 | 105 |
| 0.05860 | 17 | 268 | 16.52 | 17.00 | 60.53 | 58.82 | 110 |
| 0.06858 | 15 | 234 | 16.42 | 16.93 | 60.90 | 59.08 | 115 |
| 0.08052 | 12 | 205 | 16.28 | 16.86 | 61.42 | 59.31 | 120 |
| 0.09420 | 11 | 179 | 16.12 | 16.83 | 62.03 | 59.45 | 125 |
| 0.1105 | 9.0 | 158 | 16.00 | 16.78 | 62.50 | 59.59 | 130 |
| 0.1295 | 7.7 | 139 | 15.88 | 16.74 | 62.97 | 59.74 | 135 |
| 0.1510 | 6.6 | 123 | 15.73 | 16.72 | 63.57 | 59.80 | 140 |
| 0.1790 | 5.6 | 109 | 15.60 | 16.71 | 64.10 | 59.84 | 145 |
| 0.2109 | 4.7 | 97.2 | 15.47 | 16.73 | 64.64 | 59.76 | 150 |
| 0.2496 | 4.0 | 86.6 | 15.37 | 16.76 | 65.06 | 59.66 | 155 |
| 0.2973 | 3.4 | 77.3 | 15.22 | 16.79 | 65.70 | 59.56 | 160 |
| 0.3560 | 2.5 | 69.1 | 15.10 | 16.83 | 66.22 | 59.41 | 165 |
| 0.4305 | 2.3 | 62.0 | 15.00 | 16.96 | 66.66 | 58.96 | 170 |
| 0.5276 | 1.9 | 55.7 | 14.86 | 17.05 | 67.29 | 58.63 | 175 |
| 0.6559 | 1.5 | 50.1 | 14.75 | 17.20 | 67.79 | 58.14 | 180 |
| 0.8320 | 1.2 | 45.2 | 14.62 | 17.35 | 68.40 | 57.63 | 185 |
| 1.12 | 0.88 | 40.8 | 14.50 | 17.52 | 68.96 | 57.07 | 190 |
| 1.52 | 0.65 | 36.9 | 14.40 | 17.80 | 69.44 | 56.18 | 195 |
| 2.29 | 0.44 | 33.5 | 14.30 | 18.10 | 69.93 | 55.25 | 200 |
| 4.19 | 0.24 | 30.4 | 14.23 | 18.31 | 70.27 | 54.61 | 205 |
| 15.4 | 0.06 | 27.6 | 14.11 | 18.65 | 70.87 | 53.61 | 210 |
| $\infty$ | 0 | 26.6 | 14.07 | 18.75 | 71.07 | 53.33 | 212 |

## PRACTICAL APPLICATIONS.

### Cooling Tower.

1,000 cubic feet of moist air are forced into the base of a cooling tower per minute (barometer pressure 28.8, temperature 60° F., relative humidity 60%), and issue from the top at a pressure of 110° F. and relative humidity 90%. Required the weight of water absorbed and the heat abstracted from the circulating water.

From column (4)

$p_v = 0.518$ for 60° F.

Substitute the value of $p_v$ in equation (4), noting that

$p = 28.8$ and $h = 0.6$,

thus:

$28.8 = P_a + 0.6 \times 0.518.$

$P_a = 28.49 =$ the pressure of the dry air in the mixture entering the tower.

Similarly, from column (4)

$p_v = 2.577$ for 110° F.

Substitute the values of $p_v$ in equation (4), noting that

$p = 28.8$ and $h = 0.9$

$28.8 = p_a + 0.9 \times 2.577$

$P_a = 26.48 =$ the pressure of the dry air in the mixture leaving the tower.

If the air entering the tower were completely saturated 1,000 cubic feet would contain 0.8082 lbs. of water vapor (column 7).

At 60% saturation the vapor content will be (see equation 6)

$hd_v = 0.6 \times 0.8082 = 0.485$ lbs. per 1000 cubic feet.

In leaving the tower the weight of water vapor at saturation

$d_v = 3.73$ lbs. per 1000 cubic feet.

and $hd_v = 0.9 \times 3.73 = 3.357$ lbs. per 1000 cubic feet.

But the air passing through the tower has the temperature changed from 60° F. to 110° F., and the pressure from 28.49 ($p_a$) to 26.48.

Therefore the 1000 cubic feet of air entering per minute on leaving the tower will be increased to (equation 10)

$$v = 1000 \frac{28.49}{26.48} \times \frac{460 + 110}{460 + 60} = 1180 \text{ cubic feet,}$$

and the total weight of water vapor in this amount of air leaving the tower per minute is

$$3.357 \times \frac{1180}{1000} = 3.960 \text{ lbs.}$$

From column (3) the weight of 1000 cubic feet of dry air at 60° F. and pressure 29.921 is 76.4 lbs. The weight of dry air in the 1000 cubic feet of mixture entering the tower is

$$d_a = \frac{p_a d}{p} \quad \text{(equation 9, Boyle's law)}$$

$$= \frac{28.49 \times 76.4}{29.92} = 72.8 \text{ lbs.}$$

The heat necessary to raise the mass of air from 60° to 110° F. is

$$72.8 \times 0.2375 \times (110-60) = 866 \text{ B. T. U.}$$

The heat necessary to evaporate 3.475 lbs. of water at 110° F. is

3.475 × 1037 (= heat of evaporation at 110° F.) = 3600 B. T. U.*

The heat necessary to superheat the vapor content from 60° to 110° is

0.485 × (110—60) × 0.5 (= specific heat of lbs. superheated vapor) = 12.1 B. T. U.

866 + 3600 + 12.1 = 4478.1 = B. T. U. = total heat abstracted from the circulating water per minute.

## Evaporative Surface Condenser.

How many cubic feet of moist air and how many pounds of water spray must be forced through an evaporative surface condenser of the fan type in order to condense 1000 pounds of steam per hour and maintain a vacuum of 25 inches, barometer 29. (Atmospheric air 80° F., relative humidity 70%.) The air and vapor issue from the discharge pipe under pressure of four inches of water, temperature 120° F., relative humidity 100%.

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*Though the process of evaporation is practically continued through the whole range in the tower, we are justified in using the heat of vaporization at the highest temperature, because the liquid was at this temperature entering the tower and the vapor is brought back to this temperature when leaving the tower.

The absolute pressure in the condenser is 29.0—25.0
= 4 inches of mercury or 1.98 lbs. per sq. in.

The total heat necessary to condense and cool 100 lbs. of steam per hour at absolute pressure of 1.98 lbs. per sq. in. to 120° F. is

$$1000\ [1152-(120-32)] = 1{,}062{,}000 \text{ B. T. U.}$$

Neglecting radiation and leakage losses, this is the heat to be abstracted per hour by the air and water spray.

The pressure of the dry air in the mixture entering the condenser is (equation 4)

$$P_a = 29-0.7 \times 1.023 = 28.284$$

The pressure of the dry air in the mixture leaving the condenser is

$$P'_a = 29 + 0.294-3.425 = 25.869$$

(0.294 is the value in inches of mercury of four inches of water—the fan pressure.)

Let V = the volume of moist air (expressed in thousands of cubic feet) under atmospheric conditions entering the condenser.

In leaving, this volume will increase to

$$\frac{28.284}{25.869} \times \frac{460+120}{460+80} V = 1.175\ V$$

The weight of vapor in the condenser discharge is

$$1.175\ V\ d_v = 1.175 \times 4.883\ V$$
$$= 5.74\ V \text{ lbs.}$$

The weight of vapor in the mixture entering the condenser is

$$hd_vV = 0.7 \times 1.55 \times V = 1.085\ V \text{ lbs.}$$

The amount evaporated therefore is

$$5.74\ V - 1.085\ V = 4.655\ V \text{ lbs.}$$

The weight of dry air entering the condenser

$$d_aV = \frac{p_a d}{p} V \quad \text{(equation 9}$$

$$= \frac{28.284 \times 7.36}{29.92} V$$

and the heat absorbed by the dry air content in being heated from 80° to 120° F. is

$$\frac{28.284 \times 7.36}{29.92} V \times .2375\ (120-80) = 660\ V \quad \text{B. T. U.}$$

Heat absorbed by the evaporation of 4.655 V lbs. of water is
$4.655\ V \times 1057 = 4920\ V$ B. T. U.
(Here the latent heat is taken at the lower temperature, it being the original temperature of the liquid.)

Heat required to superheat 1.085 V lbs. of vapor from 80° to 120° is
$1.085\ V\ (120-80)\ 0.5 = 21.7\ V$ B. T. U.

Total heat absorbed by the entering air and spray is
$660\ V + 920\ V + 21.7\ V = 5601.7\ V$ B. T. U.

But this represents, also, the heat given up by the steam or
$5{,}601.7\ V = 1{,}062{,}000$

Therefore,
V = 189.5 thousands or 189,500 cubic feet of atmospheric air are necessary to condense and cool 1000 lbs. of steam under the given conditions.

The water spray to be injected per hour is
$4.655\ V = 4.655 \times 189.5 = 884$ lbs.

# THE CARRYING CAPACITY OF RAPID TRANSIT SYSTEMS.

BY THOMAS. A. BANNING, JR.*

## Statement of the Problem.

One of the most important railroad problems to be confronted at present is that of carrying capacity, by which is understood the possible rate of passenger or freight movement over a system, or past a controlling point, expressed in passengers per hour or cars per hour. Traffic has become so congested on portions of many systems that the analysis and solution of capacity problems is necessary, and methods must be devised to provide the maximum possible carrying capacity at limiting points.

These problems may be classified as relating to the carrying of passengers in and about great metropolitan centers, or as relating to through passenger or freight traffic, or both. In any case, conditions of convenience to the public, return on the investment, safety of operation, etc., must be considered and weighed before the adoption is decided upon of any method of increasing capacity.

This paper deals chiefly with the analysis of train movement in rapid transit service as related to capacity and the determination of the maximum capacity of a rapid transit system for any given set of conditions. The remedies to be applied to any specific problem must of nature be dictated by local conditions and the means at hand for meeting such conditions.

The car capacity of a railroad system for given operating conditions is usually limited by some station, signal system, or interlocking plant. Occasions arise when the movement of trains through an interlocking plant is related to their movement past some adjacent station or through some adjacent signal block; or when their movement past a station is related to their movement in an adjacent signal block, etc. In any event, there will be found usually some controlling locality wherein conditions are such as to limit the capacity of the entire system. If train schedules call for an average movement in excess of this limit, there must arise a congestion of movement in the vicinity of this limiting location. Such congestion may extend back long distances from the real seat of trouble, thus creating wrong impressions as to the actual conditions existing and at times leading to futile attempts to remedy the trouble and increase capacity.

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*Class 1907. With Board of Supervising Engineers, Chicago Traction.

The following order of discussion will be observed in the remainder of this article:

First: The capacity of single platform stations.

Second: The capacity of track, with and without block signal equipment.

Third: The capacity of double platform stations, i. e. platforms long enough to accomodate two trains at one time.

Fourth: The capacity of reservoir stations; i. e., stations so arranged that trains pass alternately to opposite sides of the platform.

Fifth: The capacity of interlocking plants.

Sixth: The capacity of the system as a whole.

**The Capacity of Single Platform Stations;**

The average frequency with which cars can be moved past a single platform station depends upon the following factors;

1. The maximum speed of trains on the adjacent track.
2. The rate of braking of the trains.
3. The duration of the station stop.
4. The rate of acceleration of the trains.
5. The length of the trains.

These may all be properly considered in estimating station capacity.

Assuming the movement of trains at stations as not affected by outside influences, such as interlocking plants, the following discussion applies. A train approaches the station at the given maximum speed, slows down and comes to rest at the platform. After a certain interval it accelerates, moves away from the platform; and as soon as safe thereafter, the following train goes through the same cycle. Fig. 1 shows these movements diagrammatically by means of distance-time curves for the case of one train occupying the platform at a time. This shows that the total time interval between trains is made up of five elements, thus:

$$T = B + D + A + L + S \qquad (1)$$

in which

B = Time lost in braking, or excess time required to run from point of application of brakes to platform over that to run same distance at full speed.

D = Duration of station stop.

A = Time lost in accelerating, or excess time required to run the distance covered in reaching full speed over that to run the same distance at full speed.

L = Time to run a train length at full speed.

S = Safe time interval between rear of one train and front of the follower, determined by the full speed attained.

Expressed in terms of average rates of acceleration and braking, length of train, etc., expression (1) becomes:

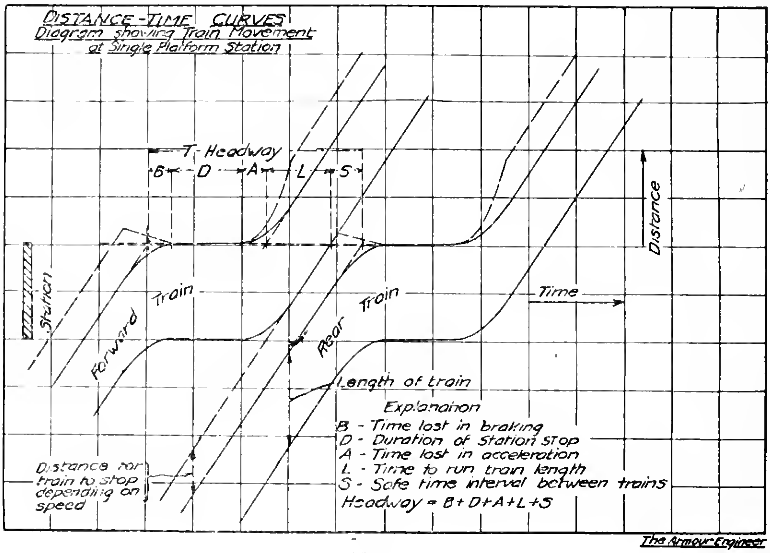


Fig. 1.

$$T = V/(2b) + D + V/(2a) + l/(1.47V) + V/2b^1 + t \qquad (2)$$

in which

V = maximum speed in miles per hour.

b = mean service rate of braking in miles per hour per sec.

a = mean rate of acceleration in miles per hour per sec.

l = train length in feet.

$b^1$ = mean emergency braking rate, miles per hour per sec.

t = time to set brakes for emergency stop.

These factors are next considered separately and as related to each other. The time losses in braking and accelerating vary inversely as the mean rates of braking and acceleration respectively, and directly as the maximum speed. In cases where the maximum speeds are high, the time loss in accelera-

tion is best found directly from the characteristic speed-time curve of the equipment during the accelerating period. The mean rate of acceleration affects only the third item of expression (1), whereas the mean rate of braking affects both the first and fifth, assuming emergency rate equal to service rate of braking. Therefore an improvement in the rate of braking allows a much greater reduction in headway than a proportional improvement in acceleration; and since an increase in rate of acceleration necessitates almost a proportional increase in first cost of car power equipment, an increase of braking efficiency is by far the more desirable of the two. Considering only items one and three of expression (1), high maximum speed is not desirable as it causes a large loss of time in accelerating and braking.

The duration of station stop is one of the most important items affecting total headway. Therefore its value must be estimated as accurately for new conditions as possible. This can be done by comparing conditions for proposed operation with present conditions. However entirely new estimates may be necessary because of a very large change of conditions such as a reduction of the total number of available stations for loading trains.

In general the duration stop is made up of four items, as follows:

$$D = G + nP + B + S \qquad (3)$$

in which

D = Duration of station stop.
G = Time to open gates or pneumatic doors.
n = Average time to load or unload one passenger.
P = Average number of passengers loading or unloading at each entrance.
B = Time to close opening and pass station starting signal.
S = Time between starting signal and actual start.

The time to open the exits should be very close to zero, because the guards should have everything in readiness to act at the instant of stopping. One second is ample allowance for **G**. **n** depends on the habits of the people, the number of passengers already in the car, size and nature of platform crowd, weather conditions, etc. Its value must be estimated for the proposed operation. Similarly **P** must be estimated. Rerouting of trains may cause passengers to crowd to some particular station, thus increasing the duration of stop of that particular station over the present value. Such contingencies must be as completely foreseen as possible. The time to close openings and to pass the signal varies with the

length of train, kind of doors or gates, etc. The use of automatic signals to notify the motorman the instant all openings are closed is desirable oftentimes. The time elapsing between the receipt of signal and actual starting should be very small, not usually over one second. The time for a train to run its length varies directly with its length and inversely as its speed.

Examination of expression (2) shows that each item may be plotted as a function of speed. The time lost in braking and the time lost in accelerating are shown by straight lines passing through the origin (lines B and A, Fig. 2). The minimum safe time between the rear of one train and the front of the next is shown by a straight line drawn at an angle with the speed axis corresponding to the emergency rate of braking, and distant above the origin by the time allowance for setting the brakes (line S, Fig 2); the duration of station stop is shown by the line D, parallel to the speed axis, and distant from it by the time of stop.

For the purposes of comparison the examples used in the following portions of this article are based on the following assumptions: Duration of stop when only loading or unloading at one side of the train, thirty seconds. Duration of stop when loading at both sides of the train, fifteen seconds. Mean rate of acceleration 1.10 M.P.H. per sec., mean rate of braking 1.50 M.P.H. per sec., allowance of one second to set brakes, block clearance distance equal to twice the emergency braking distance for the speed assumed, length of block for eight car trains not less than 500 ft., length of block for five car trains not less than 350 ft., allowance of three secs. for signal system to act in clearing. These are average operating constants corresponding to heavy elevated or subway traffic, but they relate to no particular installation.

In ordinary operation the openings on only one side of the train are available at any one time. Provision for regulated passenger movement on both sides of the train at once will double the number of openings available, thus practically reducing the duration of stop by one-half and effecting a corresponding reduction in total headway. Line $D^1$ of Fig. 2 represents the duration of station stop for this method of operation. An even better result in this case might be expected due to there being established a definite circulation of passenger movement.

The time to run a train length is represented by the hyperbola L for eight-car trains, and by $L^1$ for five-car trains. The value of L plus the value of E for any assumed maximum speed between stations gives a point on line T which shows the total train headway.

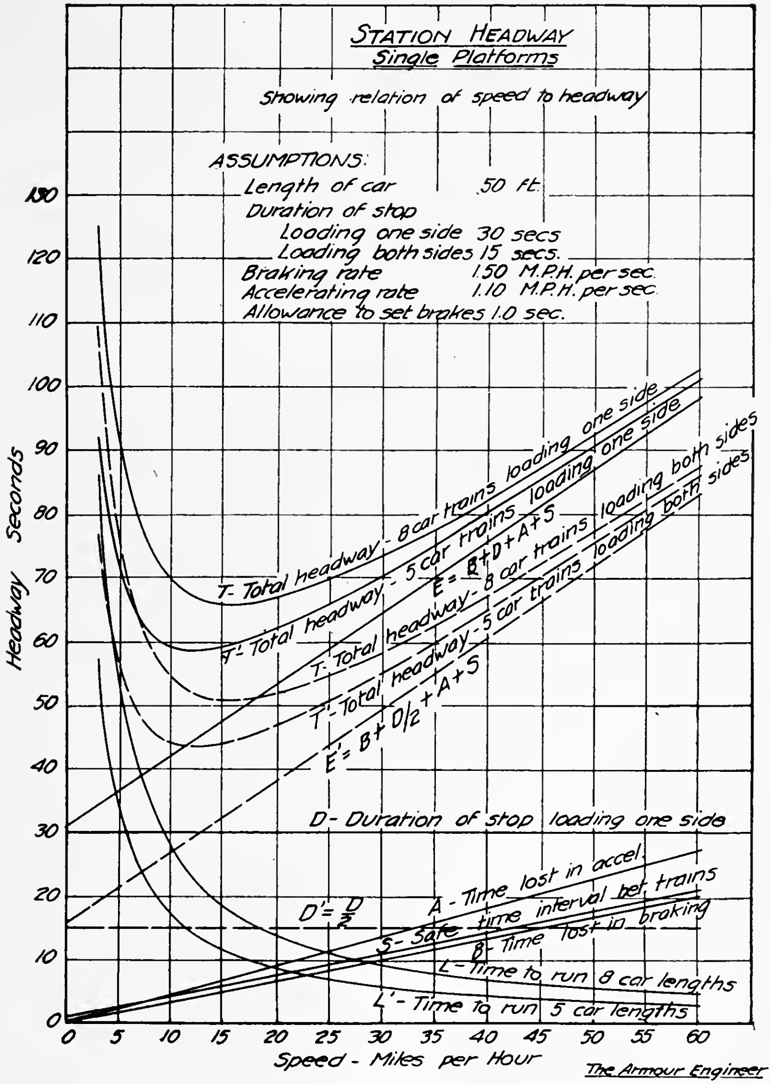
STATION HEADWAY
Single Platforms
Showing relation of speed to headway
ASSUMPTIONS:
Length of car 50 ft.
Duration of stop
Loading one side 30 secs
Loading both sides 15 secs.
Braking rate 1.50 M.P.H. per sec.
Accelerating rate 1.10 M.P.H. per sec.
Allowance to set brakes 1.0 sec.
T- Total headway - 8 car trains loading one side
T'- Total headway - 5 car trains loading one side
E = B + D + A + S
T- Total headway - 8 car trains loading both sides
T'- Total headway - 5 car trains loading both sides
E' = B + D/2 + A + S
D- Duration of stop loading one side
D' = D/2
A - Time lost in accel.
S- Safe time interval bet. trains
B- Time lost in braking
L- Time to run 8 car lengths
L'- Time to run 5 car lengths
Headway Seconds
Speed - Miles per Hour
The Armour Engineer

Fig. 2.

**The Capacity of Track, with and without Block Signal Equipment:**

The total time interval between trains operating along a track between stations may be expressed thus :

$$T = L + O \qquad (4)$$

in which

T = Headway of train movement past a given point.
L = Time to run a train length.
O = Minimum time to cover necessary safe operating space between trains.

**L** varies directly with the train length and inversely with the speed at which the train is moving. The factor **O** will depend on the maximum speed between stations, block signal requirements, emergency braking rate, etc.

**Case I: Use of Block Signal System:**

In general

$$O = C + t + t^1 \qquad (5)$$

in which

C = Time to run block clearance distance at full speed. (Distance between signal set at danger and point of track at which preceding train releases such signal.)
t = Time to make emergency brake application.
$t^1$ = Time for signal system to act.

If the block clearance distance is twice the emergency braking distance for the full speed assumed, then

$$\text{Clearance distance in feet} = 1.47\ V/b^1 \qquad (6)$$

in which symbols are same as above.

The time to run this distance during stopping is V divided by $b^1$, and the total safe headway is therefore

$$T = l/1.47\ V + V/b^1 + t + t^1 \qquad (7)$$

in which

l = train length in feet.

In any case the length of block must not be less than a full train length. Good practice requires a certain margin over and above such a requirement on account of the possibility of hauling work cars behind a regular train or other local reasons. It is here assumed that the block length will not be less than one train length plus 100 feet. Therefore the block length for eight-car trains must be at least 500 feet, and that for a five-car train at least 350 feet, assuming a length of car as generally found in elevated railway and subway practice in this country.

Expression (7) is shown graphically by Fig. 3, assuming the above minimum block length.

**Case II. No Block Signal System.**

In this case

$$T = L + S \tag{8}$$

or

$$T = 1/1.47\ V + V/2b^1 + t \tag{9}$$

Expression (9) is shown graphically by Fig. 4. This differs from Fig. 3 in the absence of the lines of time for signal system to act, and time to run a block clearance distance, and in the addition of the line of safe distance between trains. Line C of Fig 3 corresponds in a general way to line S of Fig. 4.

Fig. 5 shows the maximum cars per hour plotted against speed in miles per hour for five and eight-car trains for the preceding analysis of movement at single platforms, and along track with and without signal system. It is evident that for the conditions chosen the capacity of track, both with and without signal system is much in excess of the single station platform capacity when loading or unloading at but one side of the train. Thus for eight-car train operation between stations at 35 miles per hour, the capacity of track with signal system may be 820 cars per hour whereas the corresponding capacity of single platforms, which unload or load at but one side of train cannot exceed 370 cars per hour. This conclusion, it must be noted, is based only on the case for the assumptions shown in the figure. Any change of conditions, such as a different average duration of station stop, would change the above conclusion, at least for certain ranges of maximum speed.

There have been suggested two other methods of increasing platform capacity; namely, the use of double platforms (platforms long enough to accommodate two trains at one time) as proposed by George Weston for application to the Union Elevated Railroad in Chicago; and the use of "reservoir stations," which are stations so arranged that succeeding trains pass alternately to opposite sides of the platform. These are proposed by Bion J. Arnold for application to New York Subway conditions. Reservoir stations may be arranged to take trains from the same set of rails between stations by means of switches, or from gauntleted track.

**The Capacity of Double Platform Stations:**

Fig. 6 shows diagramatically the movement of a pair of trains past a double platform. It shows that the average time interval between trains is

$$T = \tfrac{1}{2}\,(B + D + A) + L + S \tag{10}$$

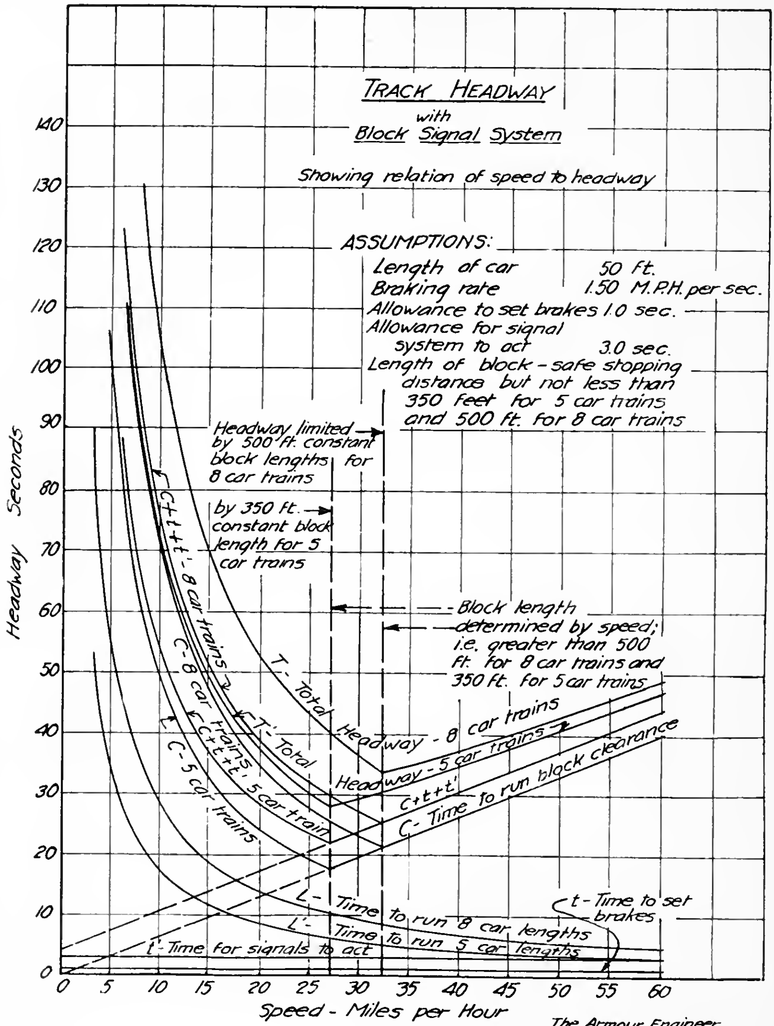


Fig. 3.

It is evident that such operation results in time saving corresponding to one-half the actual stop, plus one-half the time lost in acceleration and braking. If the total train use of both ends of the platform were equal, it would be possible to obtain an increase of average station capacity corresponding to such reduction of total headway. This would be the

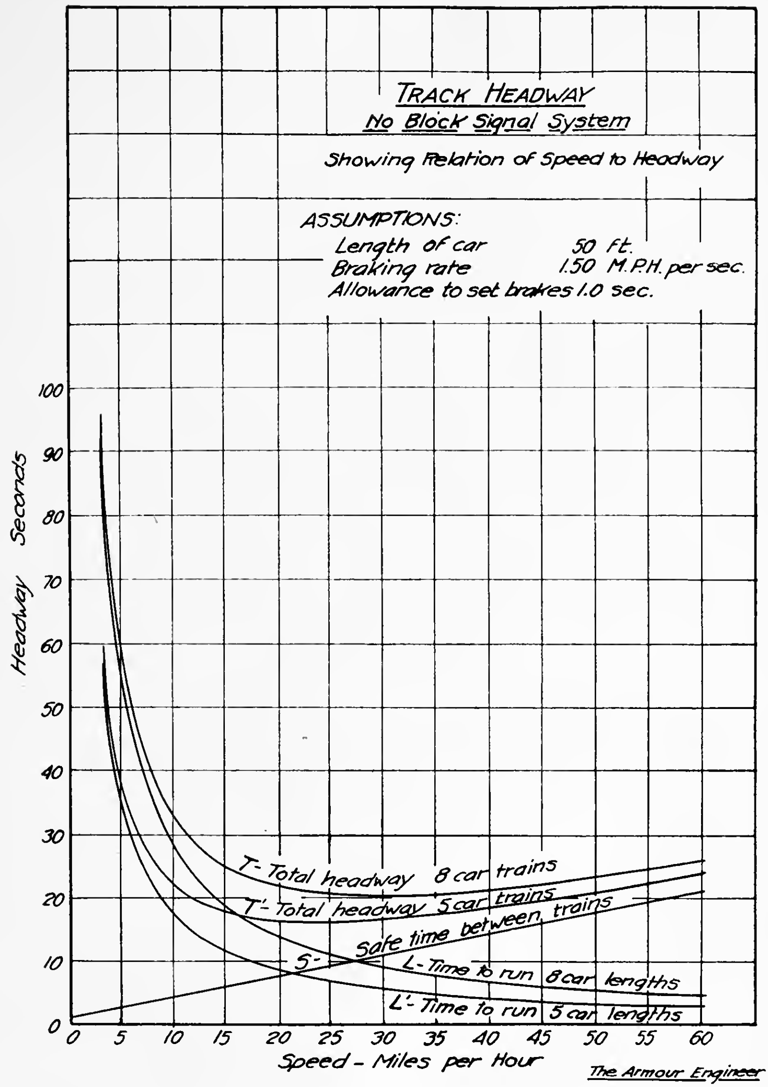


Fig. 4.

case, for example, on a main line fed by two branch lines on each of which the schedules called for equal frequency of train service, the trains from the two branches using the opposite ends of the main line platform.

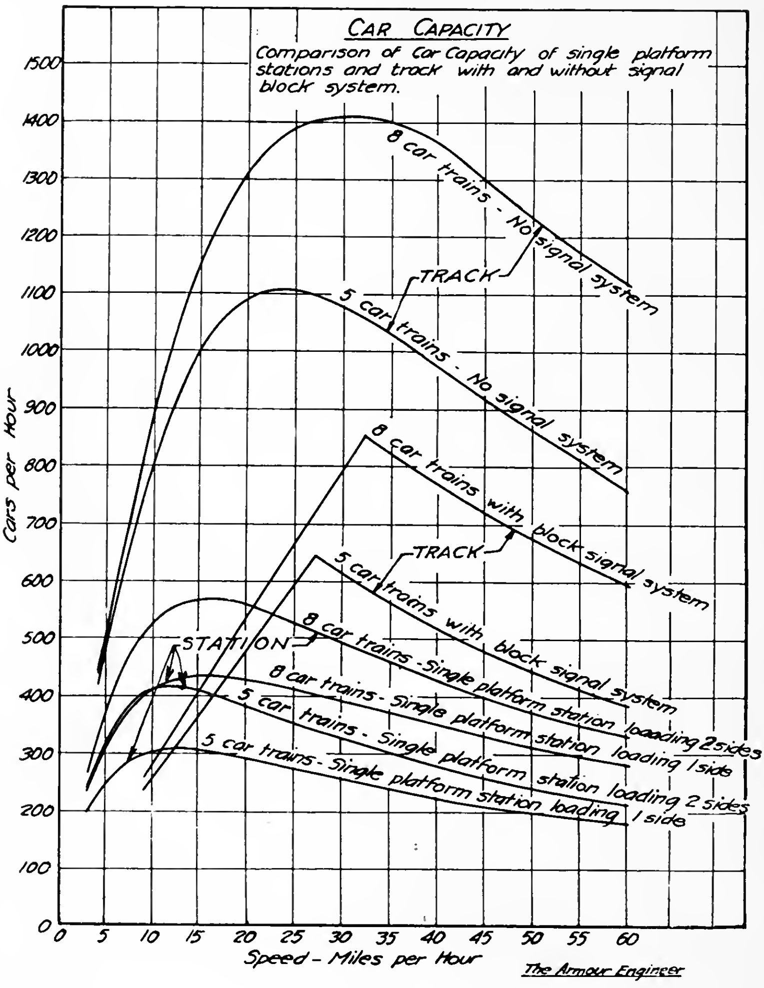


FIG. 5.

In general, the station use demanded by the two classifications of service using double platforms probably would not allow of this perfect pairing for every train movement. Following one or more pairs there would be an odd train. The saving of time due to a paired movement may be considered as equal to the difference between the neeessary time between the arrival of one train and the arrival of the next when mov-

ing singly minus the time when moving in pairs. Thus, if the station headway when moving at single platforms were 46 seconds, and the safe time between the rear of one train and the head of the following were ten seconds, there would be a possible saving of 36 seconds in total headway each time a pairing operation occurred. This would give an average net saving of 18 seconds headway per train for perfect pairing, 12.0 seconds headway per train when only every other station movement is paired, 9.0 seconds headway per train when only every third movement is paired, etc.

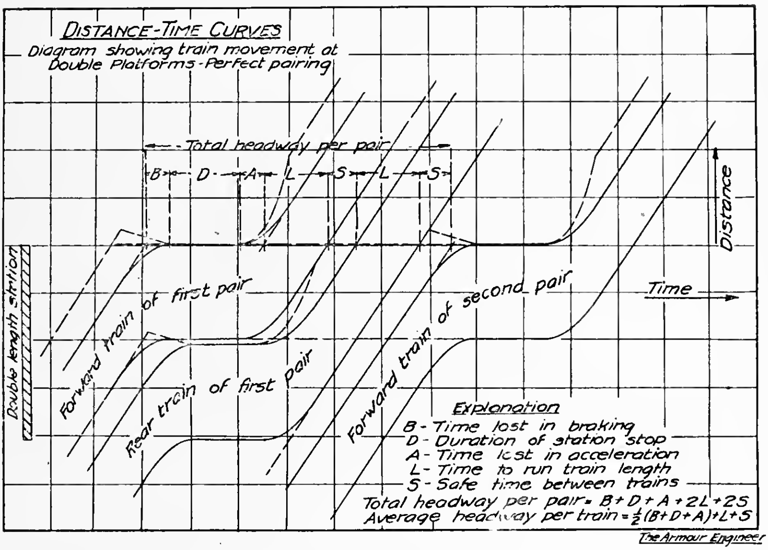


Fig. 6.

Another way of considering the saving of headway due to the pairing of trains at double platforms is as follows: It has been shown that the increase of train length by the addition of cars results in increase of car capacity of stations. It may then be considered that a pair of trains moving up to a platform has a length equal to twice the length of one train plus the safe distance between trains for the maximum speed assumed, and that the total headway of such a pair of trains will be the headway corresponding to that of a single train of this length.

In general,

$$T = [R/(R+1)] \times (B + D + A) + L + S \qquad (11)$$

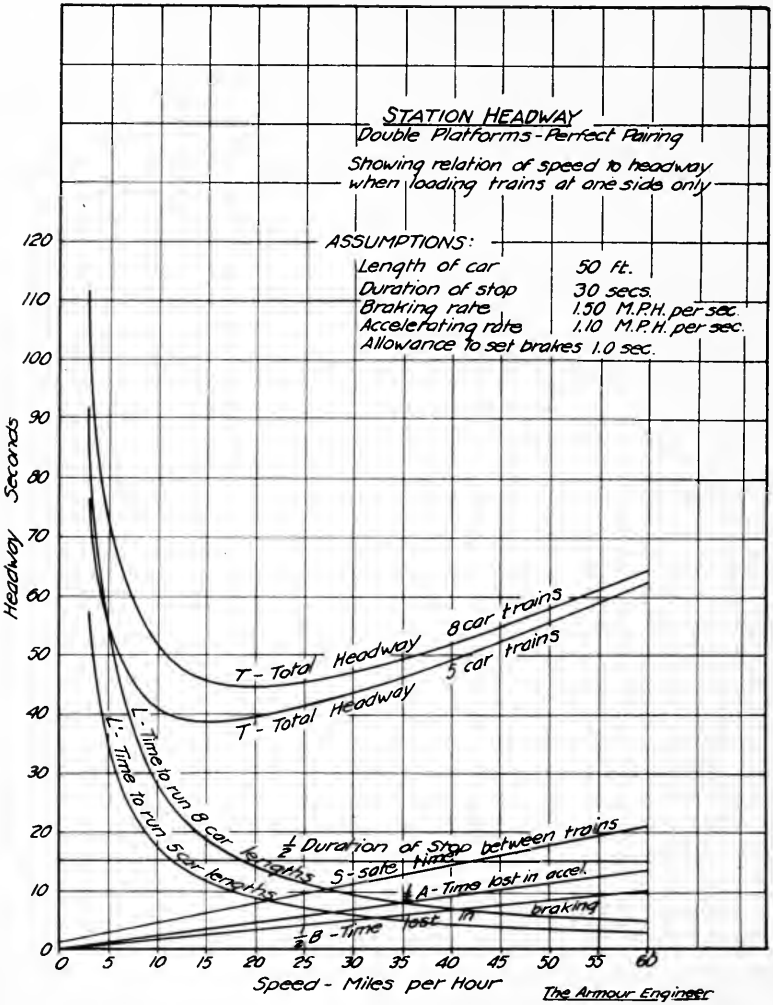


Fig. 7.

in which

T = Average headway for a cycle of trains.

R = Ratio between trains of classifications using the opposite ends of the platforms, it being understood that trains will be paired as much as possible, and that the greater value of ratio between trains be used.

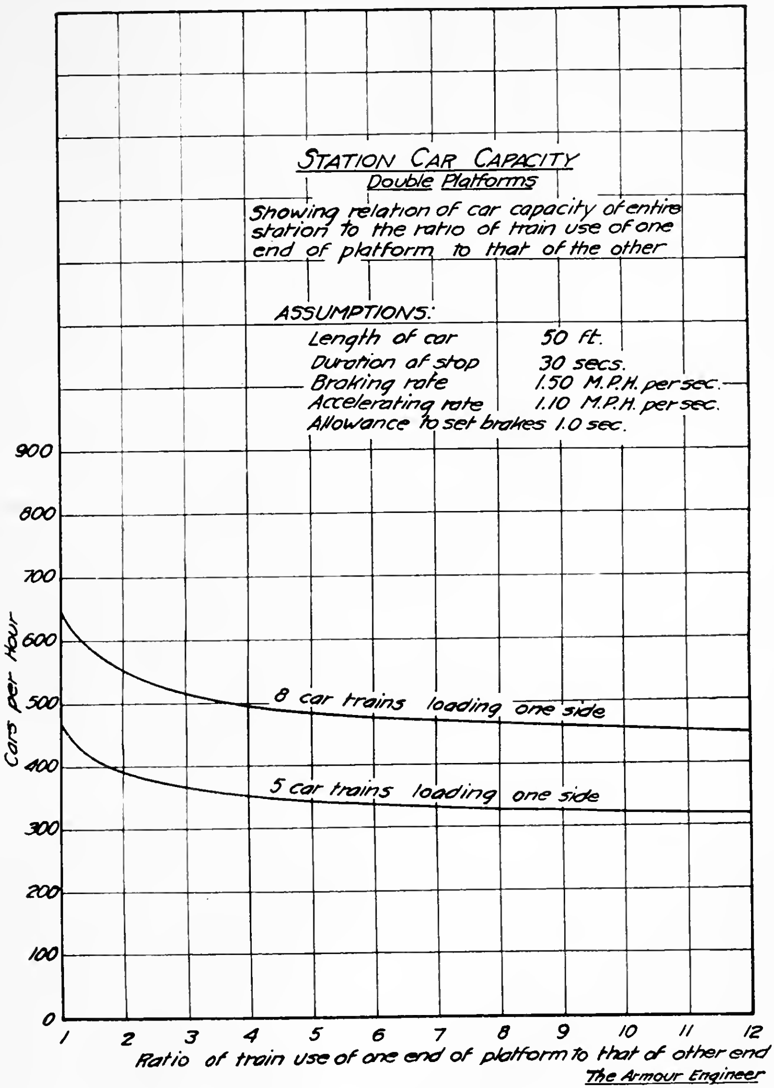


FIG. 8.

Fig. 7 shows the headway at double platforms plotted against speed in miles per hour for five and eight-car trains and with perfect pairing of train movements.

Fig 8 shows the relation of cars per hour to ratio between train use of the two ends of platform. For example: if three times as many eight-car trains stop at one end of the platform as at the other, the capacity cannot exceed 516 cars per hour for the conditions assumed. In obtaining each point on the curves of Fig. 8 the speed giving the minimum headway corresponding to that ratio was used, inasmuch as a variation of ratio gives a change of the most desirable free running speed.

**The Capacity of Reservoir Stations:**

Fig. 9 shows diagramatically the movement of trains through reservoir stations. Considering only the platform portion it is evident that a reservoir station has twice the car capacity of a similar single platform station for the same con-

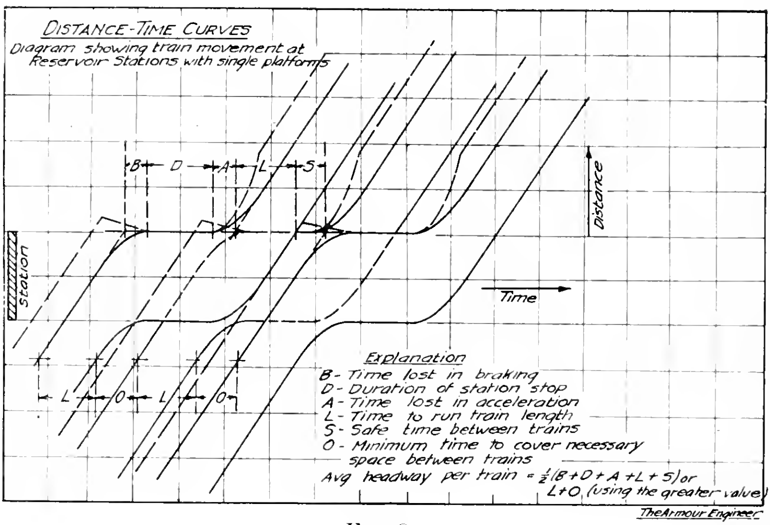


Fig. 9.

ditions. However the platform proper can not pass trains faster than they can be switched from the main line or delivered from the gauntleted track to their respective sides of the platform.

Fig. 10 shows the headway at reservoir stations as related to speed for five and eight-car train operation with the assumed conditions. It is seen that the headway is controlled by the platform proper for all reasonable speeds; therefore

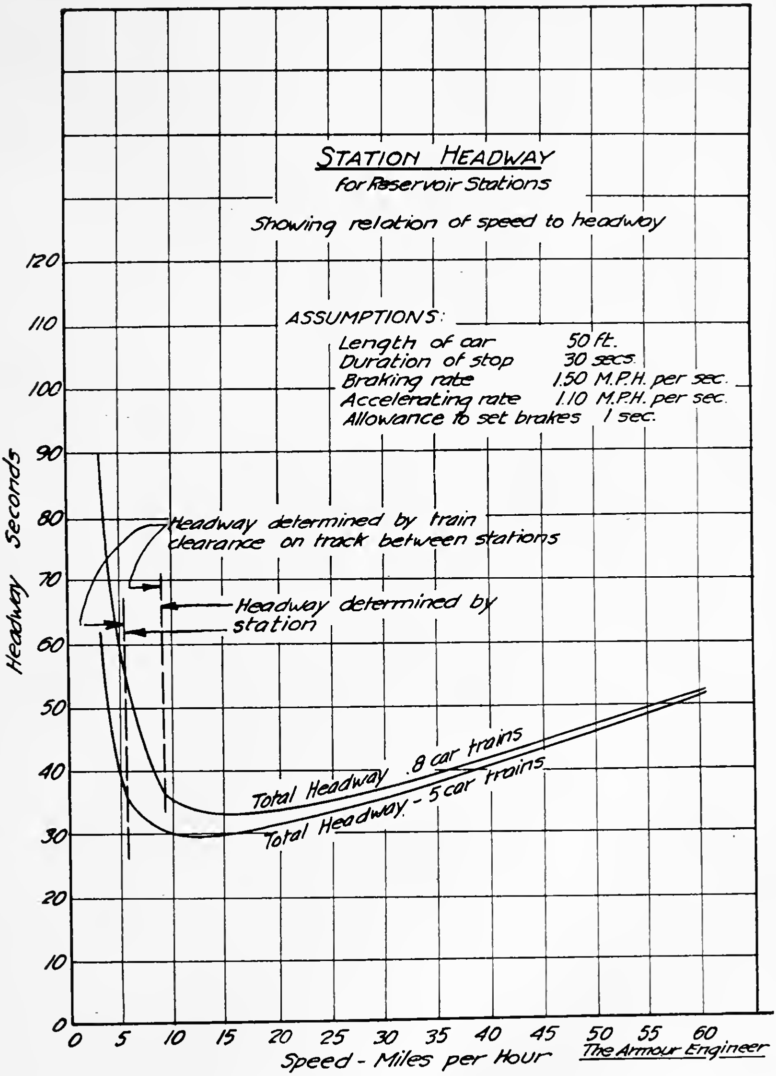


FIG. 10.

the use of reservoir stations permits double the car capacity possible when using single platforms.

We are now in a position to note the relative merits of the double platform station arrangement and the reservoir arrangement as respects improvement of car capacity of the sta-

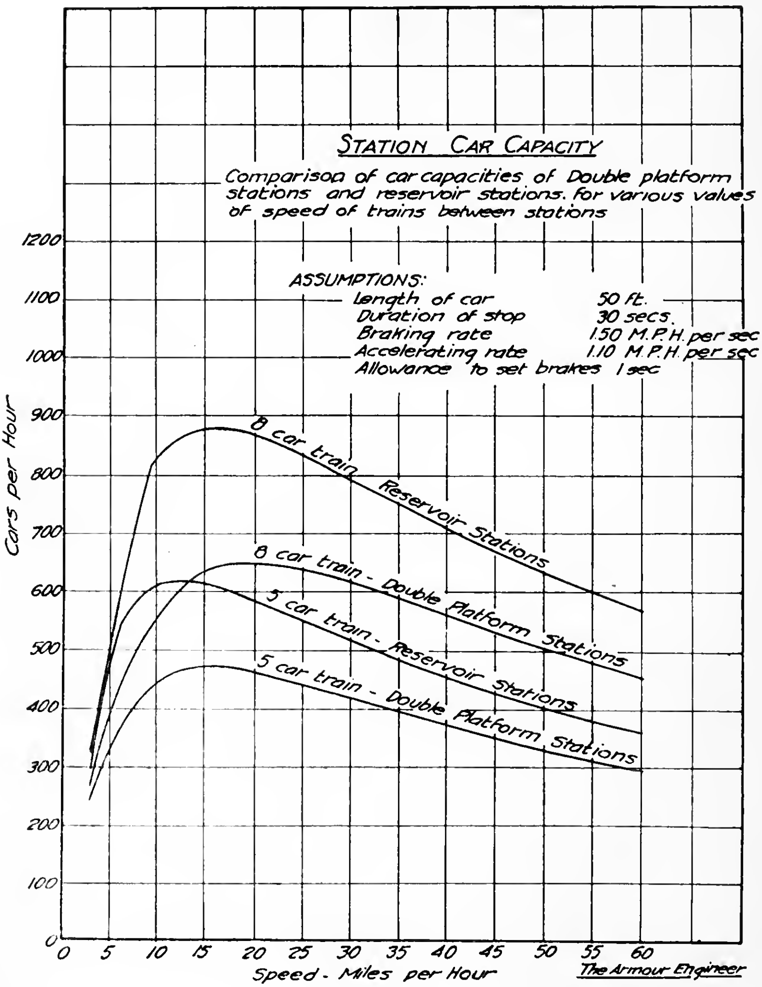


Fig. 11.

tion portion of the system. This has been done in Fig. 11. It is seen that in the cases of both five and eight-car trains for the assumed conditions the reservoir stations give capacity considerably in excess of that provided by double platform stations at the same speed.

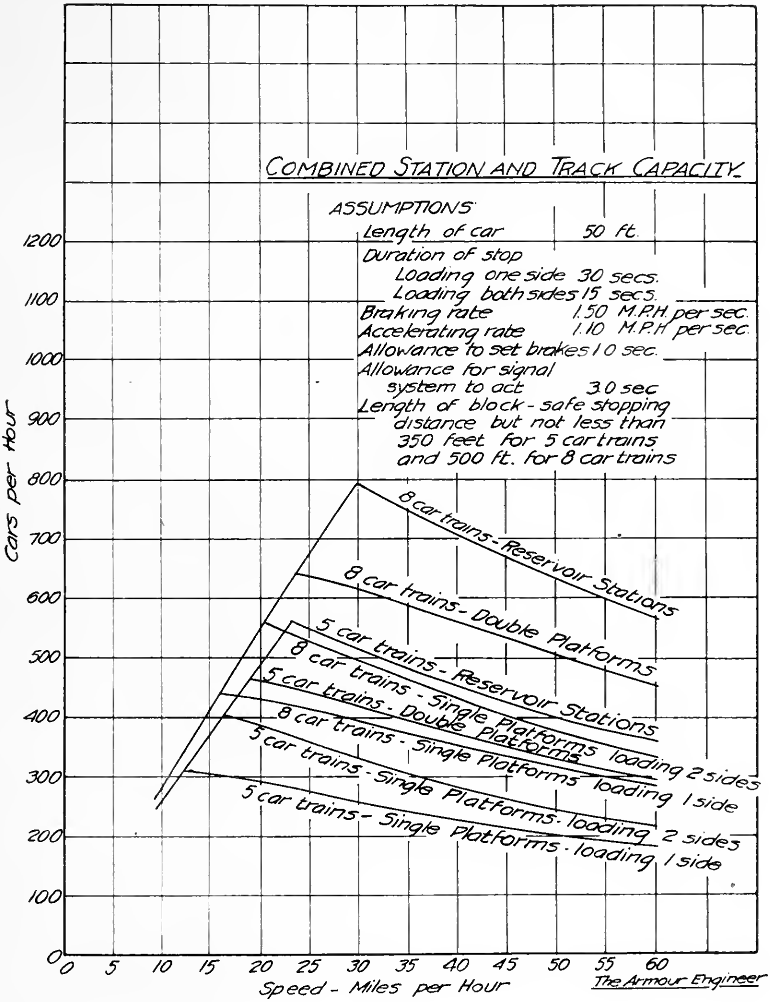


FIG. 12.

## Comparison of Station Arrangements:

Fig. 12 shows the relative car capacities of the various station arrangements above described for both five and eight-car trains.

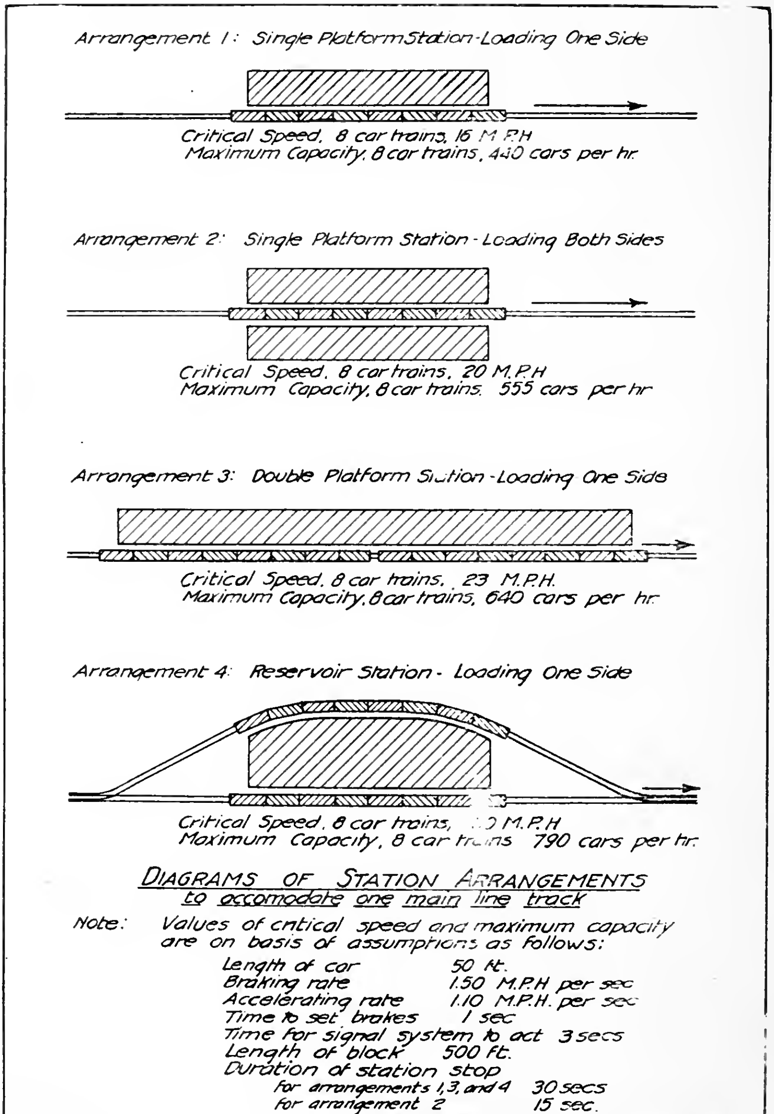
Arrangement 1: Single Platform Station-Loading One Side
Critical Speed, 8 car trains, 16 M.P.H
Maximum Capacity, 8 car trains, 440 cars per hr.
Arrangement 2: Single Platform Station - Loading Both Sides
Critical Speed, 8 car trains, 20 M.P.H
Maximum Capacity, 8 car trains, 555 cars per hr
Arrangement 3: Double Platform Station - Loading One Side
Critical Speed, 8 car trains, 23 M.P.H.
Maximum Capacity, 8 car trains, 640 cars per hr.
Arrangement 4: Reservoir Station - Loading One Side
Critical Speed, 8 car trains, M.P.H
Maximum Capacity, 8 car trains 790 cars per hr.
DIAGRAMS OF STATION ARRANGEMENTS
to accomodate one main line track
Note: Values of critical speed and maximum capacity are on basis of assumptions as follows:
Length of car 50 ft.
Braking rate 1.50 M.P.H per sec
Accelerating rate 1.10 M.P.H. per sec
Time to set brakes 1 sec
Time for signal system to act 3 secs
Length of block 500 ft.
Duration of station stop
for arrangements 1, 3, and 4 30 secs
for arrangement 2 15 sec.

FIG. 13.

It is seen that in every case the track is the limiting portion of the system for speeds up to that giving the highest capacity. Above this speed the stations determine the capacity. Fig 13 shows in outline the above four station arrangements.

In all the above studies of train movement at the stations, the time lost in braking and in accelerating has been given in terms of the mean rate of acceleration and of braking. In case these mean rates vary with the maximum speed assumed, the losses of time may be found directly from actual distance time curves of braking and acceleration.

**The Capacity of Interlocking Plants:**

An interlocking plant is considered to be a system of switches and signals arranged for train protection at crossings, intersections, etc., to prevent the simultaneous movement of trains on conflicting routes. The capacity of such a plant is determined by the length of time required for trains to move through it and clear protective devices, the order of train arrival, and the time to throw the plant when cleared. The time to pass a train through any route is

$$T = [L/1.47\ V] + [(V - V_1)^2/2\ a\ V] \qquad (12)$$

in which

$T$ = Time in seconds.
$L$ = Total distance run in feet.
$V$ = Maximum speed in miles per hour.
$V_1$ = Speed at entering, miles per hour.
$A$ = Accelerating rate of trains.

The distance **L** is that which the train must run from the point where the motorman receives the signal to the point at which the rear end of the train clears the last controlling detector bar.

The capacity of interlocking plants to handle cars is susceptible to as accurate predetermination as is the capacity of track and stations. However the order of train arrival at the plant must be known with reasonable accuracy, as must also the safe speeds while in the interlocking clearance.

The above analyses of the carrying capacities of track stations and interlocking plants presuppose that there exist no peculiar conditions of arrangement such as interference between the action of interlocking plants or block signals and the stations. In general the movement of trains along the main line of a railroad should not encounter such complications, and the analyses given should hold strictly true. Then the accuracy with which the capacity may be estimated will depend directly upon that with which the assumptions are made.

Cases presenting peculiar or individual conditions call for special analysis and it will be generally found that the use of distance time curves plotted for the complete movement is of great aid in solving them.

**The Capacity of the System as a Whole:**

The maximum car capacity of a system comprising a succession of stations, intersections, crossings, etc., is equal to that of the limiting point. There may be but one intersection or one station which is limiting, but this is sufficient to congest the entire system provided the attempt is made to run trains in excess of this limiting capacity. Whenever there arises congestion a new set of conditions comes into play which reacts on the entire system tending to further reduce its capacity. It is on this account that a certain factor of safety must be used in laying out schedules for train movement which are calculated on the basis of the theoretical distance time curve estimates as described in this article. This will insure that estimates based on the above analyses shall be conservative. The amount of this factor to be provided to take care of contingencies cannot be large; but a reduction to about 80% of the theoretical maximum capacity as calculated would seem proper to be the basis for train schedule time tables.

The closeness of the actual car capacity to the theoretical car capacity as determined by methods outlined in this article has been checked by a comparison of car counts and calculations of maximum possible car capacity in the case of an elevated railroad, the operating constants of which were known. The calculated maximum capacity was but ten per cent in excess of the actual measured capacity. This system involved several interlocking plants and other complicated situations, and the study was sufficient to check the value of the methods when applied to any proposed set of conditions.

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In general the problem of rapid transit in large cities presents itself in one of two lights or both: Either that of high schedule speed or that of accommodation of large crowds with reasonable comfort. The question most vexing to the layman and of great interest to the engineer or railroad man is "Are these two demands compatable?"

There is no question but that at the present time few if any of the great centers of population in this country or abroad have solved this question in the affirmative. And further, in an attempt to provide speed while on a journey, the solution has invariably involved great crowdedness of cars coupled with reasonable speed but not always the speed desired. In

Chicago for example, the main lines of the several elevated systems have been very highly developed with ample provision for safe and rapid travel to and from the business district, but the time saved in such rapid transit on the main lines is offset when the business district is reached by reason of the inability of the present terminus to handle all the traffic delivered. In New York, also, the subway although originally designed to provide by means of its express service very rapid transit from lower Manhattan to the region of Bronx and Van Courtland Parks has not been meeting the expectations of its projectors in regard to either speed or carrying capacity.

Of the three methods of increasing station capacity touched upon, that suggested by Bion J. Arnold for New York Subway conditions seems to meet the demands of that locality in admirable measure. The adoption of reservoir stations is shown to provide the highest carrying capacity combined with high speed, of any of the three. Moreover it is probable that the scheme in itself provides as safe an arrangement as can be found for high speed operation by reason of the separation of the trains at stations. The use of gauntleted tracks would increase this safety.

Also, the recommendation of Geo. Weston for improving congestion of the Union Elevated Railroad of Chicago is excellently adapted to the local requirements. Speed although desirable is not permissible on this railroad to any extent on account of the presence of short radius curves at its corners and small distances between station stops. Moreover the use of reservoir stations in this case is out of the question by reason of narrowness of the streets, so the use of double platforms as recommended is undoubtedly the best available means of increasing the station capacity. Furthermore the situation in Chicago is complicated by the presence of three interlocking plants.

In conclusion I wish to emphasize the importance of thorough study of a projected rapid transit system with reference to its carrying capacity, which virtually determines earning capacity, inasmuch as such study made before beginning construction will avoid the necessity in following years of inconvenient and expensive changes.

# SOME NEW BUILDINGS OF THE CHICAGO RAILWAYS COMPANY.

BY EUGENE F. HILLER.*

Under terms of the ordinance passed by the Chicago City Council, February 11, 1907, and accepted by the Chicago Railways Company, which operates the surface transportation lines on the north and west sides of this city, in January, 1908, this Company is now engaged in rehabilitating its entire properties, and it is the intention here to set forth the needs which govern the design and erection, the materials of construction, and the equipment, of the various new buildings required in connection with the business of the road under terms of this ordinance.

The three classes of buildings which provide for the greatest needs of the system, viz., car storage houses, repair shops and current transforming stations, will be discussed in the above order. The principal factor governing their design was the material lowering of the insurance rate on both buildings and contents. Other governing factors were, to increase facilities for cleaning cars and for light repairs, to provide better operating offices and quarters for the trainmen, and to expedite the removal of cars in cases of ordinary operation and also in case of emergency.

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As typical of the first class mentioned this article will take up first the car storage house located at and bounded by Twenty-fifth, Leavitt, and Twenty-fourth Streets and Irving Avenue.

The ground occupied is slightly irregular in outline, the breadth being 340 feet, and the average length about 300 feet, the building setting back about fifty feet from the street line on both Twenty-fourth and Twenty-fifth Streets in order to allow the cars to swing into the building on straight track; the ground area is thus nearly 100,000 square feet and the average height of the building above the track level is twenty-four ft. Like all the other new buildings devoted to car storage or repairs it is only one story high, the great weight of the cars and the increased insurance rate making a two-story building prohibitive.

The building stores 142 cars and is divided into six housing bays each forty-eight feet wide and 300 feet long having capacity for about twenty-four cars, giving a total valuation of about $160,000 for contents which is below the maximum value of

*Class 1906. Division Engineer, Chicago Railways Co.

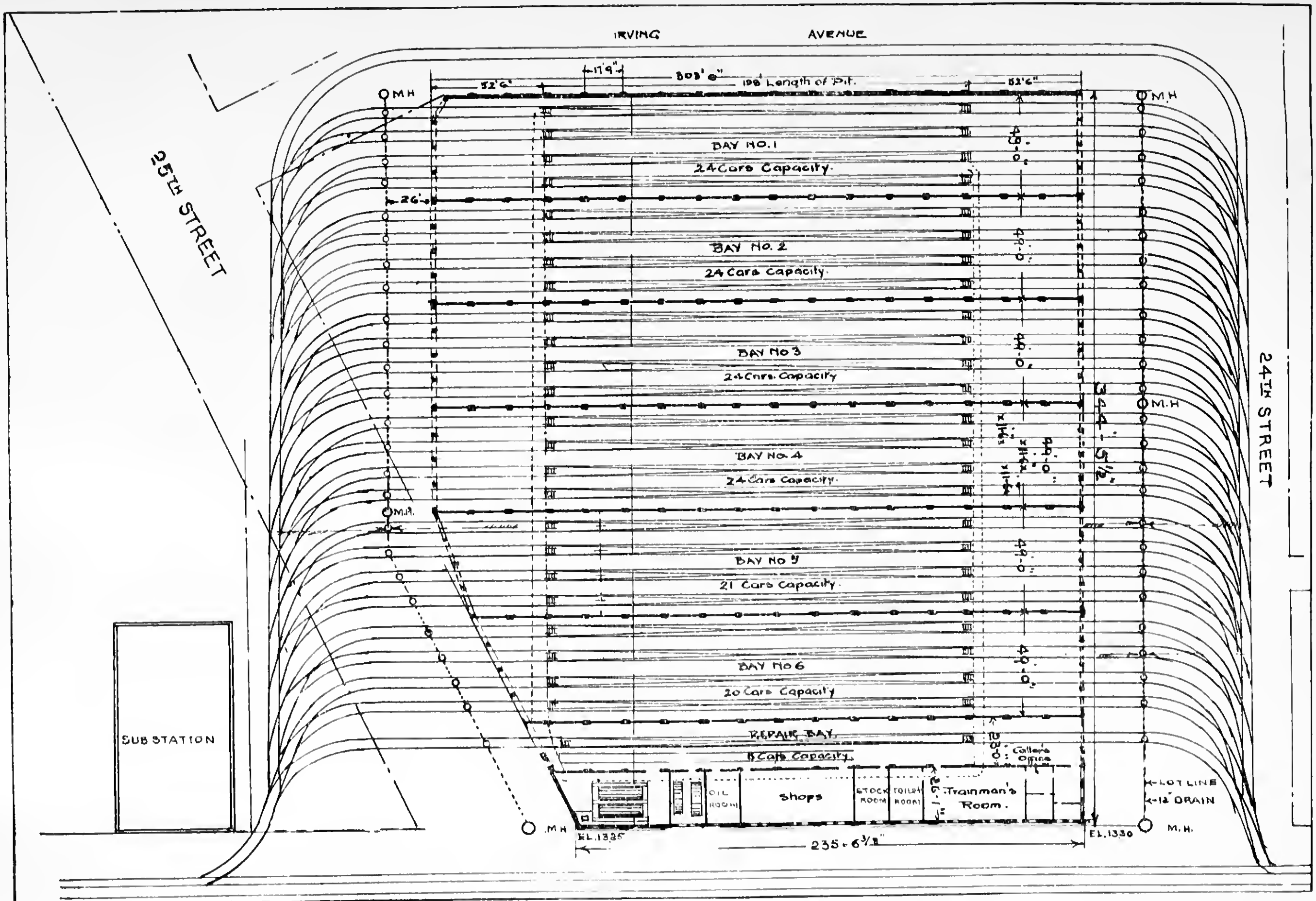


FIG. 1. BLOCK PLAN, 25TH AND LEAVITT STS. CAR HOUSE.

$200,000 insisted upon by the Underwriters, to be allowed in any one bay. At the west side of the building is a smaller bay devoted to minor car repairs, which opens directly on that part of the building devoted to the operating rooms, containing foreman's office, caller's and checker's rooms, trainmen's room, toilet room, small machine shop, oil room, fan room and boiler room; the latter rooms are separated from each other by fire walls and are protected against fire hazard in

Fig. 2. 25th and Leavitt Sts. Car House.
Forming for Roof Girders and Beams.

the repair bay by double automatic fire doors. Because of the non-combustible materials of which it is constructed but also because of its general arrangement and position of fire walls, the building is of the best form of fireproof construction.

The walls dividing the bays are all supported on concrete foundations made of concrete mixed in the ratio of one part cement to three parts sand and six parts stone, by volume, into which not more than fifteen per cent stone spalls were thrown. The design presented no special difficulty as the loads coming on these foundations only consist of their own dead load and that of the walls and roof, and the small live load on the roof. Slight trouble was experienced because of loose earth encountered, due to the filling of the ground, formerly the site of an old building.

The plant for this foundation work consisted of one large capacity mixer stationed near the middle of the building, from which wheelbarrows were carried on runways alongside the foundation form work. The foundation walls, 28 inches wide at the top, were brought one foot above grade and formed the water table for the outer walls, thus dispensing with cut stone. The brick fire walls, set on this foundation, are thirteen inches thick except at the pilasters which occur every 16 ft. 9 in. and which are 21 inches by 29 inches, and which provide bearing for the roof girders and serve as vertical stiffeners for the walls. Because of the fireproof construction of

FIG. 3. 25TH AND LEAVITT STS. CAR HOUSE.
ROOF SLAB REINFORCEMENT.

the roof it was necessary to parapet these walls for a height of 36 inches as is usually required by the Underwriters in structures of this sort. As a precaution against the possibility of fire jumping from one bay to another the skylights in adjoining bays were placed as far apart as possible.

The construction of the roof is of the "ribbed" type, consisting of a 3½ inch reinforced concrete slab resting on reinforced concrete beams about eight feet apart, these in turn being supported by reinforced concrete girders spanning the full width of each bay, 37 ft.-6 in., and resting on the brick pilasters 16 ft. 9 in. center.

The mixture of concrete is 1 : 2 : 4 by volume and was made wet enough to be very sloppy. The slab reinforcement is rib metal, a form of expanded metal in which the main rods of comparatively small area are held together by smaller transverse spacers, the main reinforcement spanning directly between supports. This material, coming in large sheets, is easily and surely placed and because of the transverse spacers, tends to prevent those expansion cracks which are liable to open in lines parallel to the main reinforcement. A complication in the design of the slab was caused by the large number of skylights, there being 15 in each panel, each about two feet by three feet.

FIG. 4. 25TH AND LEAVITT STS. CAR HOUSE.
GIRDER REINFORCEMENT SHOWING STIRRUPS.

To provide for the small concentrated loads which were brought on the skylight curbs, a little more steel in the way of round bars was added to the rib metal reinforcement.

In the design of the slab the assumption of no continuity over the supports was used as a basis of figuring, as the thinness of the slab practically made the use of top bars impossible. The total bending movement at the center was assumed at ¼ WL; this then was equated to the resisting moment of a value of .86A xAx16,000 lb., in which .86A is the distance in inches from the center of gravity of the compression of area to the center of the steel area, "A" is the area in square inches per foot of slab,

and 16,000 lb. is the stress allowed in the steel. It has been found impracticable to go to any greater refinements in the design than the above formula gives.

The beams which support this span are 8 in. x 14 in. and were designed as partially continuous, the assumption being that a total bending movement of 1/6 WL is resisted by placing enough steel at the center of the span to resist one-half of the amount, or 1/12 WL, and the same amount is required over the supports. The resisting moment was assumed as in the case of the slab, at 86AxAx16,000 lbs. The compression area is sufficient without any addition of steel or flaring of the beams and the deficiency in the area of concrete to resist diagonal tension is developed by the prongs on the main reinforcing members, no loose stirrups being required.

The design of the girders of 48-ft. span, although not of unusual length, presented the crucial part of the design. They are supported, as stated previously, on the pilasters of the fire walls, their bases being spread to give proper bearing. They are 16 inches wide, 52 inches deep at the middle and 36 inches deep at the supports and were designed as simple beams with uniformly distributed loading, the bending and resisting moments being the same as in the case of the slab design. The great dead load of the girders itself has a great influence on their design.

The stresses assumed were:

Tension in steel 16,000 lbs. per square inch.

Maximum compression in concrete 700 lbs. per square inch.

Shear in concrete 40 lbs.

Steel in direct shear 16,000 lbs., inclined at 45°.

Steel in vertical stirrups, 10,000 lbs.

As there are no adequate formulas for figuring the compression in the flanges of such deep girders considered as T beams, no reliance was placed on the adjacent portions of the slab acting as portions of the girders. The reinforcement of these girders consists of Trussed and lineal bars, the latter being bent up near the supports to help resist the diagonal tension. Because of the great depth of these girders it was thought better to interpose numerous vertical stirrups with which to hold the concrete well together, to prevent planes of division where the pouring of concrete might be stopped temporarily, and also to aid in resisting the diagonal tension near the supports. One lineal bar was run to the adjacent girders in order to tie the two together, although no dependence on this acting as top bar was assumed. The girders are flared at the junction of the slab to prevent any break at that point due to a sudden change of section and to provide a greater compression area in the concrete.

To provide for holding trolley wires, cast iron hangers were placed in the bottom of the girder boxes between the bars before pouring concrete and held in place by small nails; particular care had to be exercised in placing the girder reinforcement because of their length making them awkward to handle. The skylight curbs are about 12 in. high, from 4 to 6 inches wide and have a nailing strip imbedded to hold the skylight, and were cast after the roof slab had set; no difficulty being experienced in providing sufficient natural bond to hold them in place.

The skylights consist of two sheets of ribbed glass inclined to an angle of 30 degrees. They are framed into No. 22 galvanized iron nailed to the wooden strip in the curb and counter flashed on the outside. A wire screen, hinged on one side and held in place on the other by a wire spring, is placed a few inches below the glass to hold it in case of breakage. Plain glass is used instead of wire glass so that a fire inside the car house will cause the glass to break and provide vents for the smoke and heat to rise. The danger of fire brands being carried to these skylights from outside sources is very slight because of the class of buildings in this locality. The skylights are placed between tracks so that no matter if all the bay is occupied no portion of it will be dark. As mentioned before there are fifteen in each panel, making a total of 1,500 for the entire building.

Proper drainage, not afforded by the slope of the slab was obtained by forming ridges of a lean mixture of cinder concrete, over which a very rigidly specified four-ply tar and gravel roof, well flashed around the parapet walls and skylight curbs was placed.

Downspouts, located at every second pilaster, consist of 6 in. cast iron pipe which empty into cast iron gravel basins at their foot. They are then run into the floor drainage system, the main line of which traverses the middle of the building, emptying into the street sewers at both sides. Care was taken to make these drains large enough to prevent any possible stoppage of flow, as such would practically throw that portion of the house affected out of service. Drains are placed at frequent intervals in the pit floors, the concrete being sloped to these drains. To provide for water supply ¾ in. risers and hose bibbs are placed at frequent intervals throughout the house.

The track is about four feet above the pit floor, the latter extending for about two-thirds of the length of the building. Cast iron columns spaced six feet apart support 85-lb. T rails which in turn act as supports for the concrete slab between

tracks. In place of every sixth column is built a concrete buttress wall which provides additional stiffness to the structure. At the columns also two angles, riveted back to back, are placed at right angles to the track and span between columns to provide bearing for the rails. The slab, designed for a total load of 250 lbs. to take care of concentrated loads caused by jacking up cars is reinforced by twisted bars spanning both ways spaced 12-in. centers. A slight crowning was built in this slab to cause any water which might fall on it to be thrown into the pit below, thence to be drained off through the floor drains.

The 85-lb. rails inside the car house are spliced directly at each end to the 140-lb. girder rails of which the special work outside is made. The area outside is paved with granite paving blocks sloped so as to drain into gutters between the tracks about 25 feet from the building.

The heating system is of the indirect type, a double system of fans being situated in the east office bay; the hot air is then conducted in concrete ducts below the floor at each end of the line of pits and opening directly into them. Single automatic fire dampers are placed at each fire wall in these ducts and, as further precaution, each outlet is provided with an automatic damper, making it impossible for fire to communicate from one bay to another.

The toilet room previously mentioned, has a cement floor and contains numerous urinals, wash bowls and closets, the latter being separately revented and in separate compartments. It has been the aim to procure as serviceable fixtures as possible and to provide the trainmen with the best accommodations. The foreman has a separate toilet room. The walls in the office portion are all plastered, the outside walls being furred by metal strips and metal lath. It was not thought necessary to use lath upon the inside walls because they would probably be free from dampness. The floors in the other office partitions are $\frac{7}{8}$ in. dressed and matched maple, nailed to cross sleepers, 16 in. cc. held in cinder concrete.

Each of these rooms is a separate unit, from a fire insurance standpoint, not connecting with any other and connecting with the repair bay only through double automatic fire doors. Numerous Burt ventilators are placed in the roof.

The repair bay is 22 feet wide, has a capacity of five cars and contains one track, similarly constructed to the tracks in in the housing bays; and also a short track at the side to hold trucks as they are removed from the cars. A traveling crane of 10 tons capacity and supported on "I" beams fastened on top of large brick pilasters, traverses its entire length and because

of limited head room, in spite of the fact that the roof over this bay is raised above the other portions, the carriage is hung below instead of being placed above the crane.

The roof over the entire building is covered with a very rigidly specified five ply tar and gravel roof, well flashed around the skylight curbs and end walls. After three layers of felt have been laid a thorough mopping is called for, the last two layers then being placed. After three months the loose gravel is to be swept off and the roof recoated.

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This then completes in detail the main points involved in the construction of this car house. The next building to be considered is that housing the car shops at Fortieth and Park Avenues. It differs materially in design from the carhouse just described in that it is covered with tooth roofs and is not divided into three track bays as is the other. In reality this shop is composed of three buildings, a carpenter shop 223x150 ft., a paint shop of the same size, and storage rooms, one 50x158 ft., the other 25x118 ft., and these are all separated by fire walls and the openings in them protected by vestibules with automatic fire doors. The shops are built to within 54 feet of the building line on each street, leaving room for a transfer table at each street front by which cars are moved from one shop to another. This obviates the necessity of transfer table inside the building, requiring a dangerous opening, viewed from a fire protection stand-point, in the fire wall separating the two shops.

Each of the shops, about 33 feet from the floor to the ridge of the saw tooth, are divided crossways into three spans, the two side ones being 48 feet and the center one 60 feet. The original design called for built up steel trusses to span these distances, which were to be fireproofed by metal lath and cement plaster, but on taking figures on this construction, the cost was found to be so great that it was deemed advisable to change to reinforced concrete construction, which, while saving a little in cost, has added advantage of requiring no further attention for maintenance after once it is constructed.

The reinforced girders of shorter span are carried on one end by brick walls and on the other by concrete columns protected by steel cylinders. The 60 foot girders are carried entirely by these columns. The idea of governing this construction of the columns was to provide a form for the concrete and at the same time protection, after completion, against chipping and breaking off by the mechanics working about the building.

The girders were designed as simple beams, as outlined before, the load coming on them being uniformly distributed,

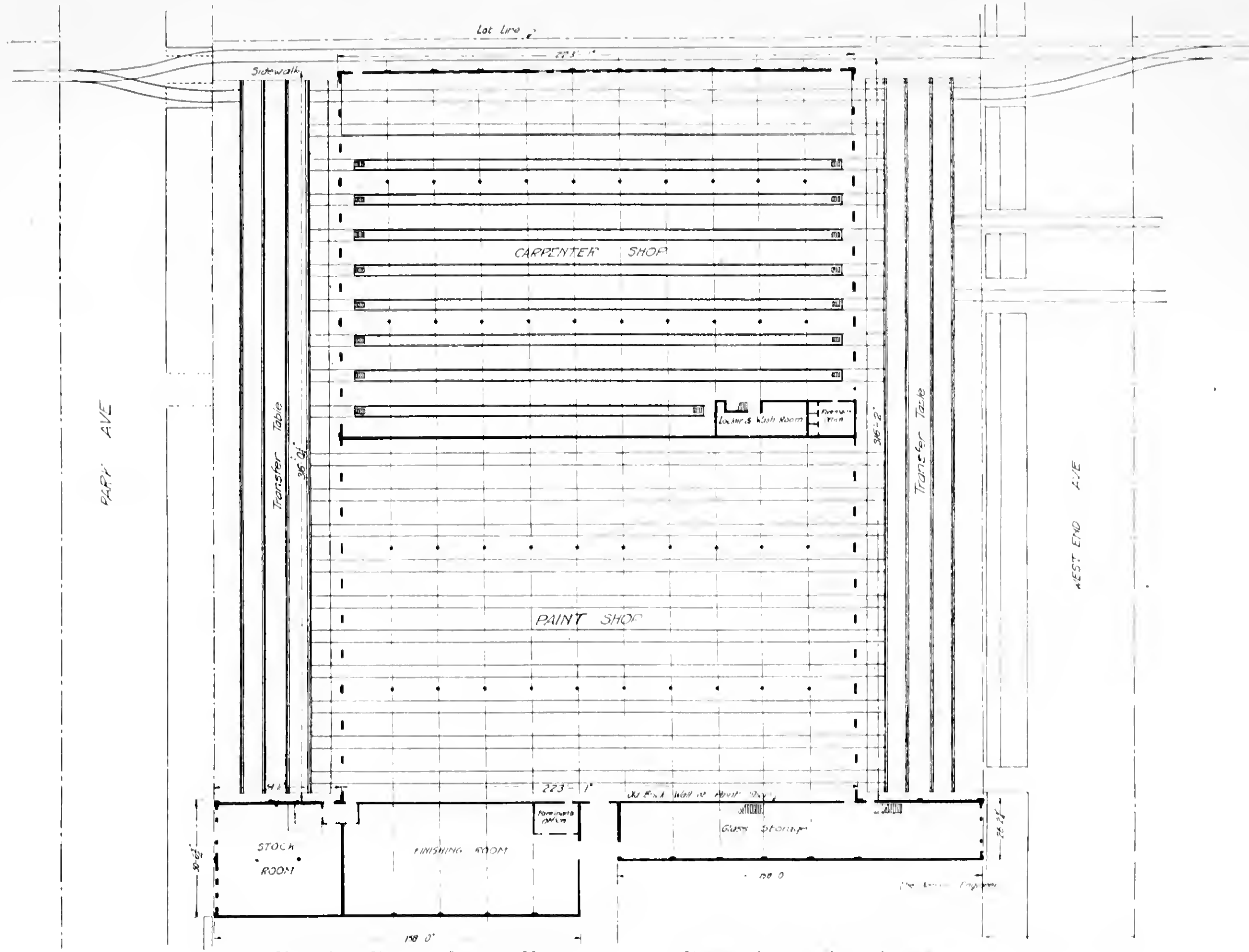


Fig. 5. Block Plan, Fortieth and Park Aves. Car Shops.

since the beams carrying the roof framed into them at intervals of 17 feet. The 60 foot span has a width of 16 in. and a maximum depth at the center of 70 in., its upper part was extended, after casting, for a height of 14 in. in order to form a curb for the saw tooth windows. The beams supporting the slab are of ordinary design and are 10 in. x 20 in., the upper flange being broadened to create more compression area. In addition at each column a horizontal strut is run across to the adjacent column to provide for transverse stiffening of the building.

The roof slab is composed of small reinforced concrete joists, formed by spacing 12 in. x 12 in. hollow tile, 4 inches high, 16 inches on centers; the whole is then covered with one inch of concrete to provide a smooth base for the roofing. Each joist is reinforced with bars of .38 sq. inch section at the center, the end section being partially sheared off to provide diagonal tension members, thereby adding greatly to the stiffness of these narrow joists. Top bars of the same section are spaced 32 inches apart, securely tying one roof panel to the next. The tile, placed adjacent to each other longitudinally, but without any connection with each other, are stopped several inches from the beams in order to form a T section. The gutters formed at the joining of the roof slab and of the window curbs are drained at the dividing walls into cast iron downspouts passed through the building, and after passing three gravel basins into the floor drainage system.

The carpenter shop has only floor pits, the floor between tracks being concrete on fill instead of reinforced concrete slabs as in the car houses; this being done to provide for the heavy loads due to supporting cars on jacks. To provide for illumination beneath the cars incandescent electric lights are recessed in the sides of the pits at intervals of about 4 feet. Each pit is sloped to drains placed about 75 feet apart. A ¾-in. pipe also is run through the buildings to provide water cocks at every fourth column for washing purposes.

The paint shop has no pits, but the floor, of concrete on fill, is sloped to drains situated at convenient points between rails at intervals of about 50 feet.

In one corner of the carpenter shop is located a small two story portion about 14 feet wide and 50 feet long, which contains on the first floor, the foreman's office and a locker and wash room for the employes, on the second floor two sets of fans and coils for the indirect system of heating for both shops, one for each shop. The air is drawn through the windows in the saw tooth roof, passes through the coils and is then forced by fans, 108 inches in diameter, through galvanized iron ducts hung to the roof girders and carried the length of the building in two longitudinal lines adjacent to the two rows of columns.

The store room, mentioned previously, having a width of 25 feet, is spanned from wall to wall by heavy I beams which support a reinforced concrete slab floor. The lower floor is devoted to glass storage, an immense amount of which is used annually to replace broken windows on cars. The second floor houses a toilet and locker room for the employes of the paint shop, and, being immediately beneath the saw roof, is admirably suited to the purpose. The other portion of this floor houses a sign painting room and a curtain repair room, both of which have additional light from the sides.

The second store room, having a width of 50 feet, is devoted to the storage of paints to be used in the paint shop and also to the finishing of the interior wood work of the cars

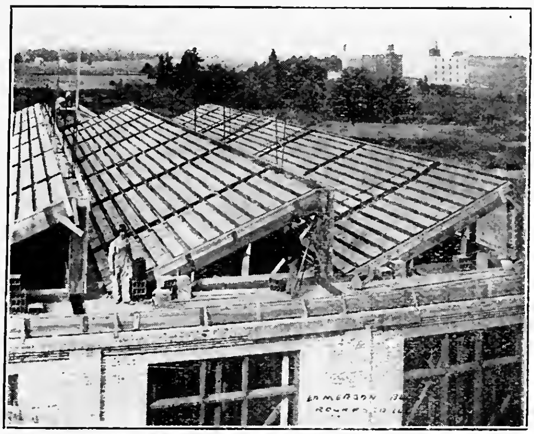

Fig. 6. Showing Method of Laying Tile and Concrete for Saw Tooth Roof.

Passage ways and doors have been so arranged that communication between these different portions of the building is facilitated as much as possible, consistent with the Underwriters requirements of as few communications as possible consistent with the utility of the buildings.

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In describing the first building it was mentioned that a small machine shop was provided in the office bay as an adjunct to the car station. This has been enlarged, in the car house at Dewey Court and Clark Street, into a large sized building, in order to provide for repairs in the north district.

This building is one story high, except for storage rooms, and of superior construction, i. e., the steel beams and columns supporting the balcony floor, which is 14 feet wide and follows

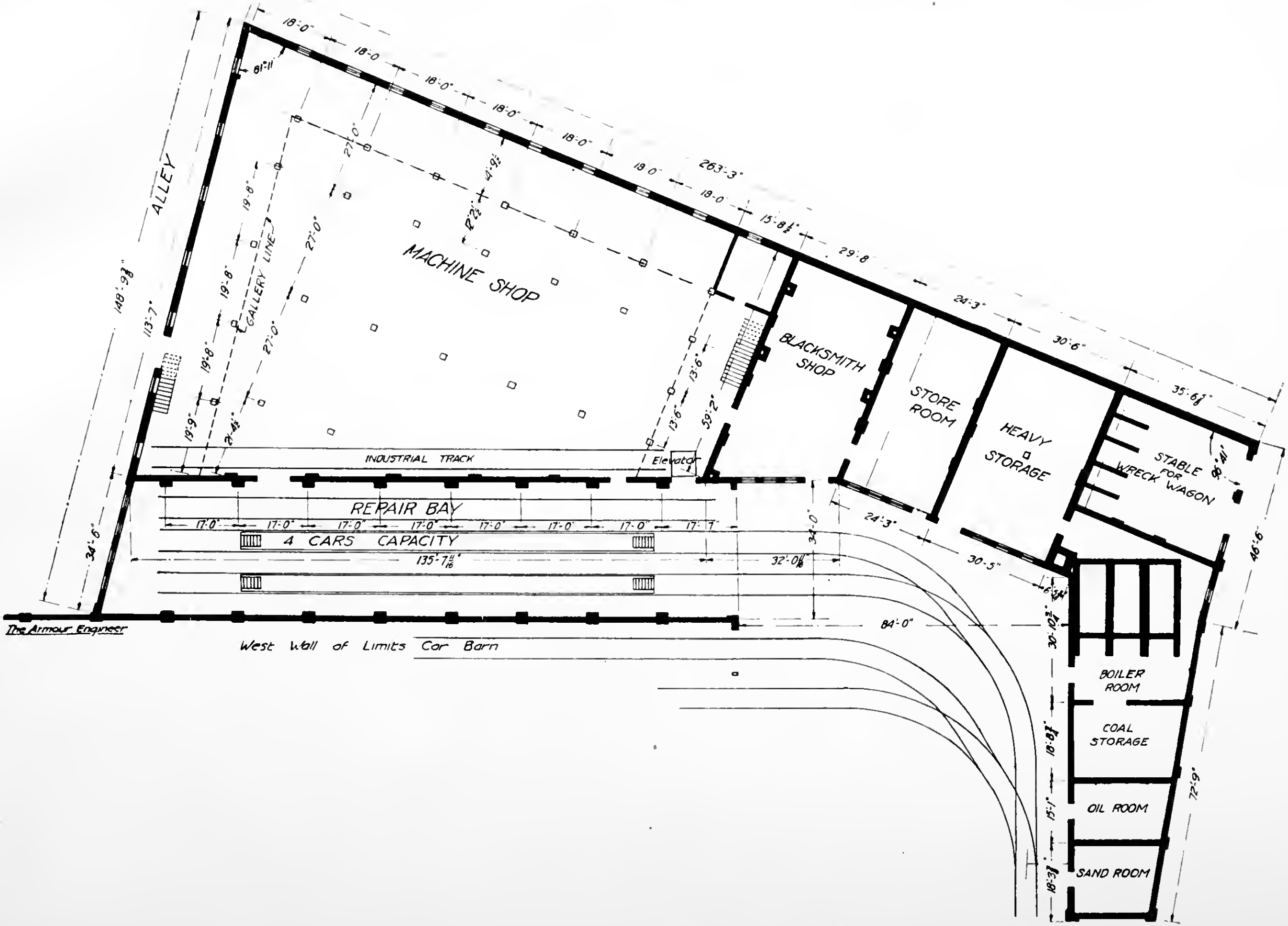


FIG. 7. SHOP AND STORAGE BUILDING ADJACENT TO LIMITS CAR HOUSE (DEWEY CT. AND CLARK ST.)

three sides of the shop, are protected against fire by a covering of concrete. The other columns which support the roof, about 25 feet high, are light latticed sections and are unprotected, except those which also support the balcony, which are fireproofed to the roof girders.

In this building 3x12x18 in. book tile, cemented together and covered by tar and gravel roofing, are supported on T irons clipped to the supporting I beams. At frequent intervals are placed large skylights, each about 8x10 ft.; these admirably light the building. To provide for ventilation numerous vents in different portions of the roof were built independently of the skylights. Additional light was also secured by inserting in the west wall which is on a lot line, metal frame and ribbed wire glass windows, hinged and equipped with fusible links.

All the heavy machines are placed on the ground floor on concrete beds. A 3-in. yellow pine flooring, splined and resting on a bed of bituminous concrete, i. e., concrete mixed with coal tar, to provide a firm and waterproof foundation, covers the remaining area. It has been in service under heavy wear and has stood the test excellently.

The lighter machines for armature winding and repairs are on the balcony, which is a reinforced concrete slab resting on steel beams. One portion of this balcony is devoted to storage room and contains also a foreman's office on the edge of the balcony and overlooking the entire shop.

Various rooms adjoining this shop and separated from it by fire walls and automatic doors are devoted to forge shop, storage rooms, fan room, oil room and sand room. A boiler room with three low pressure boilers is also provide to supply the fan system of indirect heating for the car house, in a manner very similar to the Twenty-fifth and Leavitt Streets car house.

Directly adjoining this shop building and forming a portion of the car house is to be built a heavy traveling crane spanning the entire bay.

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The third class of the buildings under construction is for transforming alternate current of high voltage to direct current of 550 voltage for use on the lines. The buildings of this class are of "superior construction," and are 50 feet high to provide for a crane the full length of the building; they are 50 feet wide and 90 feet long and have one floor about six feet above grade and a basement underneath which contains the wire ducts, fan systems for cooling chambers, and battery room. The floor is of reinforced concrete supported on steel beams, openings being left for the passage of cables. The rotary

foundations are built entirely independent of the building foundations and are brought up to the level of the floor. Each station is designed to accomodate three rotary converters and the accompanying transformers, these being supported above floor upon enameled green brick.

The sewage and drainage systems have been so arranged that the least possible dampness is allowed to remain in the building and the downspout servers are brought outside the building at each corner, instead of through the basement, as is usually done.

A distinctive feature of these buildings is the interior construction. The floors are of tile imbedded in concrete grout, and the walls for a height of six feet are a green enamelled brick, above that point a white enamel brick is used nearly to the roof, except at the brackets which support the crane runway and at the corners of the building, where the same green brick are employed in a frieze which gives these places an appearance of greater strength. The steel columns are all imbedded within the wall and thus no unsightly pilasters or any projections occur which will allow lodgment of dust, the bane of substation operators.

The roof trusses are supported on the upper ends of the same columns that hold the crane runway. As in the previous case book tile supported on T irons and covered by tar and gravel roofing are used over the entire roof except for the space occupied by a double slope puttyless skylight eight feet wide and running the full length of the building. This is supported by a steel curbing and is securely fastened and flashed all around. All windows are metal frame and wire glass and are operated by mechanical devices controlling different panes in parallel.

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Because of the various uses to which these buildings are to be put it has been inadvisable to design them along the same lines and build them with the same materials. Each building is a study by itself, involving a balancing between initial cost, insurance rate, and maintenance charges. We believe that we have arrived at the proper solution of the equation involving these three variables.

# PITOT TUBES FOR AIR.

BY A. H. ANDERSON, M. E.*

The description of a new form of Pitot tube for measuring the flow of low pressure air in pipes and an explanation of the calculations involved are the subjects of this paper.

Consider the case of a blower discharging air into the atmosphere through a circular pipe. A tube "A" as in Fig. 1, with the nose pointing up stream, the upper end connected by a rubber tube to a U-tube containing water, will indicate a head "h" in that U-tube, which is due partly to velocity (impact) and partly to static pressure, and it is therefore necessary to separate these two heads in order to determine the velocity.

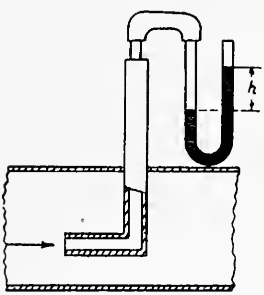


FIG. 1.

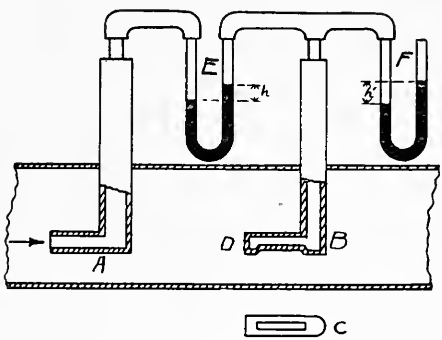


FIG. 2.

Fig. 2 shows tube "A" connected as before. Tube "B" is connected to the other leg of the manometer and also to manometer "F." The nose of tube "B" is plugged and in the bottom of the horizontal part is a slit about twenty times as long as it is wide, as is shown at C.

A tube consrtucted as in "B" will not be affected by the velocity of air but will indicate the true static pressure. In the left leg of "E" the pressure is that due to velocity plus static pressure, in the right leg static pressure acts; the head "h" is the difference of velocity plus static minus static or simply velocity pressure. The head "h" is the static pressure.

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Fig. 3 shows these two tubes combined, and also the stuffing box for insertion into the walls of a pipe so the tube may be slid up and down and readings taken at various points in the pipe. "C" is the open tube directed against the current leading to the tip for rubber connection "B." "E" is the slit opening into the annular space surrounding the inner tube and terminating in the tip "G." "S" is the wall of the pipe, "R" a bushing, "Q" the plug to fit into it, and "O" a cap screwing down on the packing N to prevent leakage. The pointer "T" indicates the location of the tube.

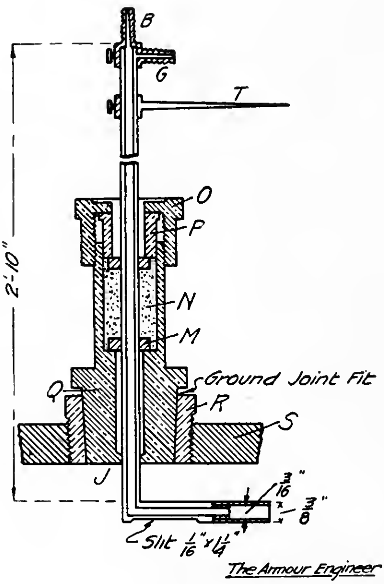


Fig. 3.

Fig. 4 shows the Pitot tube connected to the U-tubes. Where velocities are low, a manometer of the Eames draft gauge type is used, as is shown in the figure.

Consider the tube in Fig. 1. The impact of the air will sustain a column of water in the U-tube equivalent to the head causing the velocity. For example, if the velocity of the air is 20 foot per second, the head causing that flow is

$$H'' = \frac{2g}{(\text{velocity})^2} = \frac{2 \times 32.2}{20 \times 20} = 6.2 \text{ ft. of air.}$$

One inch of water is the equivalent approximately of 70 feet of air and the head of water shown in the U-tube will be

$$\frac{6.2}{70} = 0.09 \text{ inches of water}$$

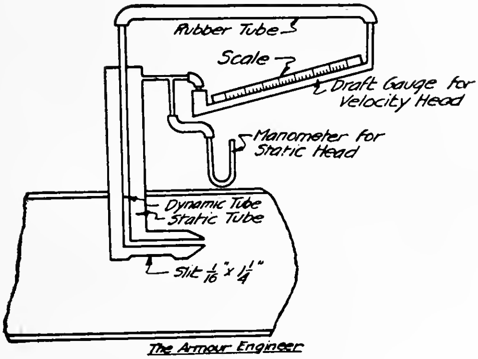


FIG. 4.

However, in addition to the impact, the static pressure will act and increase the head shown in the U-tube. Say this static pressure is one ounce per square inch, which is equivalent to 1.73 inches water, and the actual reading in the U-tube will be

$$1.73 \times .09 = 1.82 \text{ inches of water.}$$

The head presented by .09 is called the "velocity head," that represented by 1.73 is the "static head," and that represented by 1.82 the "dynamic head."

If now the velocity in the pipe has a constant value at all points in a section, it is only necessary to note the readings of the U-tubes "E" and "F" in Fig. 2; call these "h" and "$h_1$" respectively. The velocity head in feet of air is 70h, and the velocity is

$$V = \sqrt{2gx70\ h}$$

If the cross sectional area of the pipe at the point of measurement is S feet, then volume delivered per second is

d x v x S lbs.

The dynamic head in feet of air is

$$70\ (h \times h_1),$$

and the work done in moving the air against the pressure $h_1$ is

$$dSv \times 70\ (h \times h_1) \text{ foot- pounds per second.}$$

The density of the air in the pipe depends on the static pressure. For moderate pressures it may be taken as .076 pounds per cubic foot. For pressures over 15 inches of water it must be calculated in order to avoid serious error.

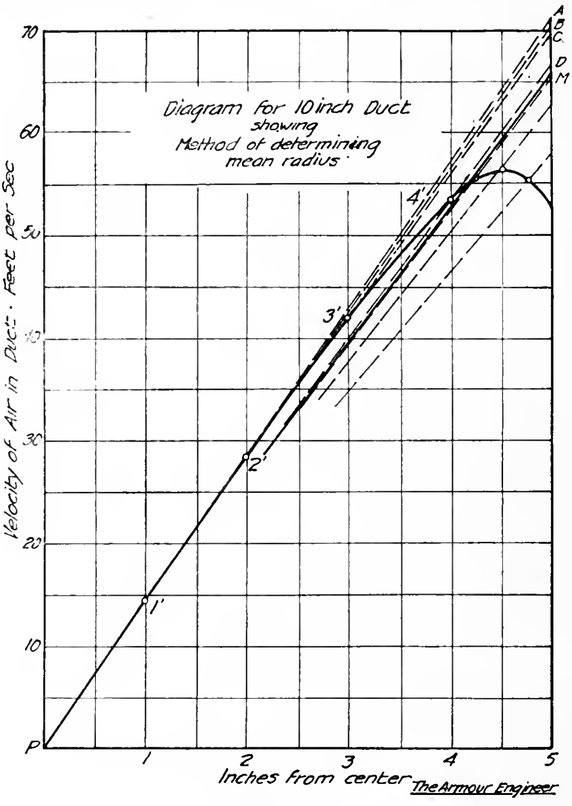


FIG. 5.

The assumption that the velocity is constant at all points in a section of the pipe is not correct. The velocity is less at the walls of the pipe than at the center, and it is therefore necessary to determine the mean velocity. The following method is given by R. Burnham (see Engineering News, Dec. 21, 1905.) Place the tube at the center of the pipe and read h and $h_1$, then place the tube an inch nearer the upper wall and again read h and $h_1$; repeat for intervals of one inch until the upper wall is

reached, then proceed similarly to the lower wall, then back to the center. Four velocity heads "h" are noted at 8 inches from the center, two on each side, etc. Average the four heads at the same distance from the center. In Fig. 5 results are plotted for a ten inch pipe. The radius is laid off to scale on the horizontal axis. The velocity in feet per second at one inch from the center is laid off to scale on the vertical axis erected from 5 as OA; connect A and P and note the intersection $1^1$. Next lay off the velocty at 2 inches from the center and lay it off on the perpendicular erected from 5 as OB; connect B and P and note the intersection $2^1$. The other velocities are plotted similarly and the corresponding points $3^1$, $4^1$, etc., obtained. When all these points are connected with a smooth curve the area of P, $1^1$, $2^1$, $3^1$, OP, is integrated. Next construct a right triangle having area equal to that under the curve, and PO for its base. In Fig. 5 such a triangle has the hypotenuse PM. The velocity represented by OM is the average velocity, and the radius determined by dropping a perpendicular from the intersection of PM with the curve is the mean radius, meaning that if the tube is placed at that radius, the head will give the mean velocity. This mean radius remains almost exactly constant for all velocities.

For approximate results the mean radius may be taken as .8 of the actual radius of the pipe. Thus in a ten inch pipe the tube is placed 4 inches above or below the center. In a 24 inch pipe the tube should be placed 9.6 inches from the center. For more accurate results the mean radius should be determined.

Following are the results from a run made for a circular duct 10 inches in diameter, delivering air from a blower into the atmosphere, from which Fig. 5 is plotted.

| Dis'ce from Center, In. | Velocity H'd, In. Water. | Static H. In. W |
|---|---|---|
| 0 | 1.16 | 0.1 |
| 1 | 1.17 | 0.1 |
| 2 | 1.15 | 0.1 |
| 3 | 1.13 | 0.1 |
| 4 | .97 | 0.1 |
| 4¼ | .97 | 0.1 |
| 4½ | .89 | 0.1 |
| 4¾ | .57 | 0.1 |
| 4½ | .89 | 0.1 |
| 4¼ | .90 | 0.1 |
| 4 | 1.10 | 0.1 |
| 3 | 1.19 | 0.1 |
| 2 | 1.21 | 0.1 |
| 1 | 1.21 | 0.1 |
| 0 | 1.21 | 0.1 |
| 1 | 1.21 | 0.1 |

| | | |
|---|---|---|
| 2 | 1.18 | 0.1 |
| 3 | 1.15 | 0.1 |
| 4 | 1.09 | 0.1 |
| 4¼ | 1.07 | 0.1 |
| 4½ | .99 | 0.1 |
| 4¾ | .95 | 0.1 |
| 4½ | .95 | 0.1 |
| 4¼ | 1.01 | 0.1 |
| 4 | 1.03 | 0.1 |
| 3 | 1.11 | 0.1 |
| 2 | 1.15 | 0.1 |
| 1 | 1.17 | 0.1 |
| 0 | 1.17 | 0.1 |

**Average Results.**

| In. from Center | Static Head | Velocity Head In. Water | Velocity Head Ft. Air | Sq. Root of Ft. Air | Velocity in Ft. per Sec. |
|---|---|---|---|---|---|
| 0 | .1 | 1.18 | 78.0 | 8.83 | 71.0 |
| 1 | .1 | 1.19 | 78.5 | 8.85 | 71.0 |
| 2 | .1 | 1.17 | 77.3 | 8.80 | 70.5 |
| 3 | .1 | 1.14 | 75.2 | 8.69 | 69.5 |
| 4 | .1 | 1.05 | 69.5 | 8.32 | 66.8 |
| 4¼ | .1 | 1.01 | 66.5 | 8.15 | 65.5 |
| 4½ | .1 | .94 | 62.0 | 7.87 | 63.0 |
| 4¾ | .1 | .78 | 53.0 | 7.28 | 58.3 |

In this test the ratio between inches of water and feet of air was 66.

# THE IMPACT MACHINE AND ITS EQUIPMENT FOR TESTING DRAFT GEARS.

BY MILTON C. SHEDD.*

Armour Institute of Technology possesses the best facilities in the country for the impact testing of car wheels, axles, brake gearing, draft gears, or other apparatus which in actual use are subjected to sudden shocks or collisions. A year ago a fifty-foot standard Master Car Builder's Drop Test Machine, designed and built by the Whiting Foundry Equipment Co., was erected by the shop force of the Institute on Dearborn Street. Views of the machine are shown in the accompanying engravings Figs. 4, 5, 6 and 7. The standards are fifty-five feet above the foundation springs, allowing for a sheer drop of forty-five feet. The hammer or drop, as ordinarily used, weighs 1660 pounds, but additional weights may be added to make it 2000 pounds in all. This will give a maximum force of 90,000 foot pounds of energy available for testing purposes. The hammer is provided with a magnetic clutch which is automatically released by a striker set at the desired height. The power for elevating the hammer is obtained from a ten horse-power, motor driven hoist conveniently housed at the side of the machine.

The base of the machine is a very heavy solid block of cast iron, mounted on heavy coil springs which take up the shock of the blow. If desired, this base may be blocked up so that there is a solid impact transmitted direct to the six foot concrete foundation. Heavy bolts through this foundation hold the standards rigidly to it, but for additional rigidity guy-ropes are fastened from the top of the standards. A four-ton differential block and chain, mounted on a movable arm from the side of the standards permits of the easy placing of apparatus to be tested. Any size or shape of apparatus may be held in place by a very complete equipment of frames and riggings.

While an impact machine may be used for a variety of tests, this one has been especially equipped for testing draft-gears, which are used behind couplers and bumpers on all steam and electric cars to absorb the shock of the two cars coming together. A great variety of these devices are made, and lately, there has been much discussion as to the relative efficiencies of the different makes. The underlying principle of all the gears is the action of various friction devices, aided to a large extent by spiral or elliptical springs. A perfect gear

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*Class 1909. Mechanical Engineering. Armour Institute of Technology.

is one which will absorb the entire shock, without transmitting any of it into the underframe of the car, and of course, every gear is perfect for a very light blow, the efficiency decreasing as the blow becomes greater. The utility of the drop test machine in this kind of testing may be illustrated by the fact that a drop of fifteen feet with the 2,000 pound hammer produces the same effect on a gear as the collision of an average train of cars running at a speed of fifteen miles an hour. A drop of twenty feet or more will usually injure the gear or its frame. The movement of the gear is the compression of its spring. This is usually obtained to find the limit of usefulness of the gear, because when the compression is a maximum, the gear is solid, and the force is transmitted direct to the underframing of the car.

To find the amount of the force transmitted by a gear for various blows, an automatic absorption dynamometer was designed as thesis work by the writer, and has just been completed in the Institute shops. A cross-section view of this is shown in Fig 1. Its principle is essentially that of the Miner Dynamometer, the only other one ever made, but its details are quite different. A removable eye-bolt gives convenience in handling. The gear rests upon the steel receiving plunger, and the force of the blow causes a certain pressure to be exerted on the water or similar liquid which fills the enclosed cavity underneath the plunger. Since water is incompressible (practically), the pressure will be transmitted by the brass reducing plunger to the lower water-filled cavity, but at a much reduced pressure owing to the difference in area of the two surfaces of this lower plunger. In fact, since the diameter of the receiving plunger is 19 inches, and the diameters of the two surfaces of the reducing plunger are four and twelve inches, respectively, then a pressure of one pound per square inch in the lower cavity indicates a total pressure of 3250 pounds on the receiving plunger. The plungers have free motion in their collars, good lubrication being provided by V-shaped grease rings around the plungers.

Water is supplied to the two cavities by a pipe connecting with a small tank placed some 25 feet above the ground, thus insuring a pressure in the dynamometer sufficient to raise the plungers from their seats and to press the diaphragms against their respective metal surfaces. Automatic check valves close the instant the pressure inside is raised, and practically no water leaks past them. To allow for sudden leakage or slight compressibility of the liquid, the plungers are designed to have a maximum travel of one-eighth of an inch; and the diaphragms will not be damaged at all if the plungers strike solidly. These diaphragms are of "spinning brass," spun to fit the metal

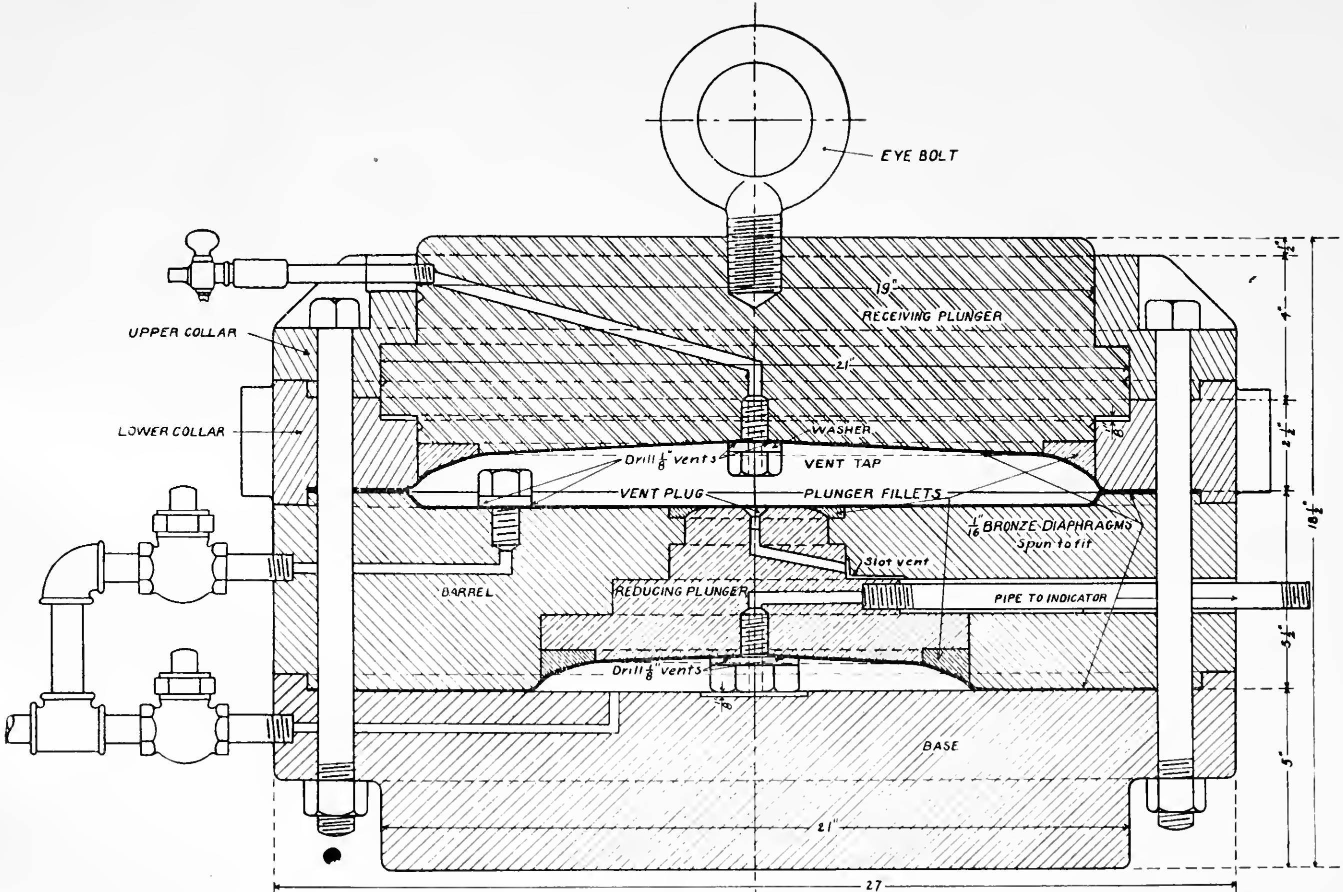
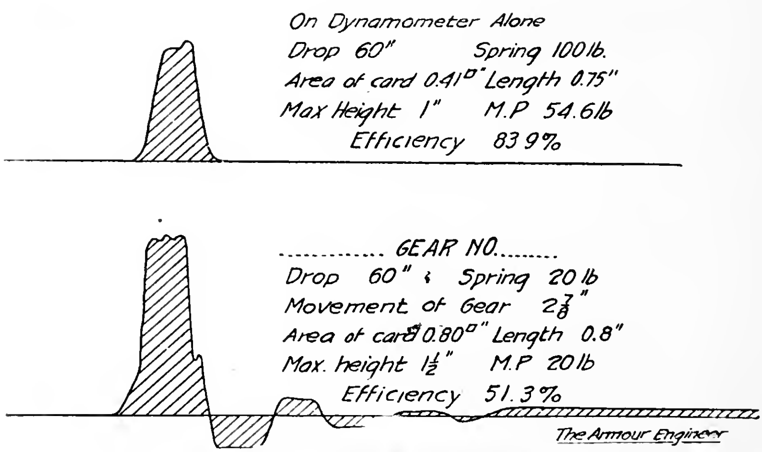



FIG. 1. CROSS SECTION OF DYNAMOMETER.

surfaces, and entirely enclose the liquid. In case they should break, provision is made for the instant escape of the liquid to the outside, where its presence can be easily noted. The liquid usually used is water mixed with some liquid like alcohol to lower the freezing point and so prevent damage in very cold weather.

The dynamometer was designed for a safe maximum pressure of 2000 pounds per square inch in the upper water chamber, which would be caused by a drop of 25 feet on the dynamometer alone. Care was taken to have perfect castings and




FIGS. 2 AND 3. DYNAMOMETER INDICATOR CARDS.

good workmanship on all the various parts, so that if it should be necessary, a drop of 50 feet can be made with perfect safety. Of course, if the base of the impact machine should be blocked up on its foundation, the actual depression of the appratus would be very small, and the pressure on the liquid would be enormous for large drops, according to the principle that the work stored in the falling hammer equals the pressure on the dynamometer times the depression of the same.

The lower reservoir is connected by means of flexible piping to the indicating device. This was designed by Mr. A. H. Anderson, Instructor in the Mechanical Engineering Department, and has been made from an ordinary indicator by the addition of a small motor to provide continuous high speed rotation of the drum. Instead of the usual indicator cards, paper cards prepared with certain chemicals which leave a black mark when written on with a brass stylus, are used.

Thus a sharp brass point may be used instead of the usual pencil, producing clear-cut, accurate cards. The point is pressed against the paper by means of a small solenoid, which is made to act by the closing and breaking of electrical connections. A tuning fork may be attached to this to trace its vibrations on the paper, and so indicate the time of the action of the spring; but this knowledge is not of any special benefit in the usual test.

To make this solenoid automatic, an adjustable switch, has been designed and completed. The device is attached to a wire cable and may be raised or lowered according to the height of the gear in the machine. A striker on the hammer designed for uniformly accelerated motion strikes a hardened steel roller at one end of lever arm, which act causes connection to be made between two insulated contact knives. At the same time, it throws up a weight which strikes against an adjustable stop and falls back on the lever, disconnecting the contact knives. The length of time the point is against the indicator card can thus be nicely adjusted by changing the height of the movable stop. The lever arm and weight are made of aluminum to make the inertia effect as small as possible. If made of a heavier metal, the enormous acceleration of the falling weight would shear off the lever before its inertia of rest would be overcome.

Let us now take up the actual indicator cards obtained by the above described apparatus. Since the dynamometer and the base of the machine are themselves mounted on springs, these springs will absorb a large amount of the energy of the drop, and this must be allowed for in calculating the efficiency of the gear.

The amount of energy absorbed varies with the height of drop, and is constant for every drop at any height. Hence we may determine the efficiency of the dynamometer for every drop, and plot a standard calibration curve of it.

Fig. 2 shows a typical card from a drop on the dynamometer alone, and Fig. 3 shows a card from the test of a gear, both cards being taken at a five foot drop. The necessary data for the calculations are given with each card.

The ratio of the movement of the small piston in the indicator to the movement of the pencil point is 18 to 100. Therefore, for a height of card of one inch, the travel of this piston is 0.18 inches. The work done on the indicator piston is the product of the mean pressure per square inch exerted against it by its area in square inches, multiplied by the travel of the piston in feet, whence the work on the indicator piston equals

$$54.6 \times \tfrac{1}{2} \times \frac{0.18}{12} = .41 \text{ foot pounds}$$

Now since 1 pound in the indicator piston equals 3250 pounds pressure on the top of the dynamometer, the total energy absorbed by the dynamometer is $.41 \times 3250$ or 1332.5 foot-pounds.

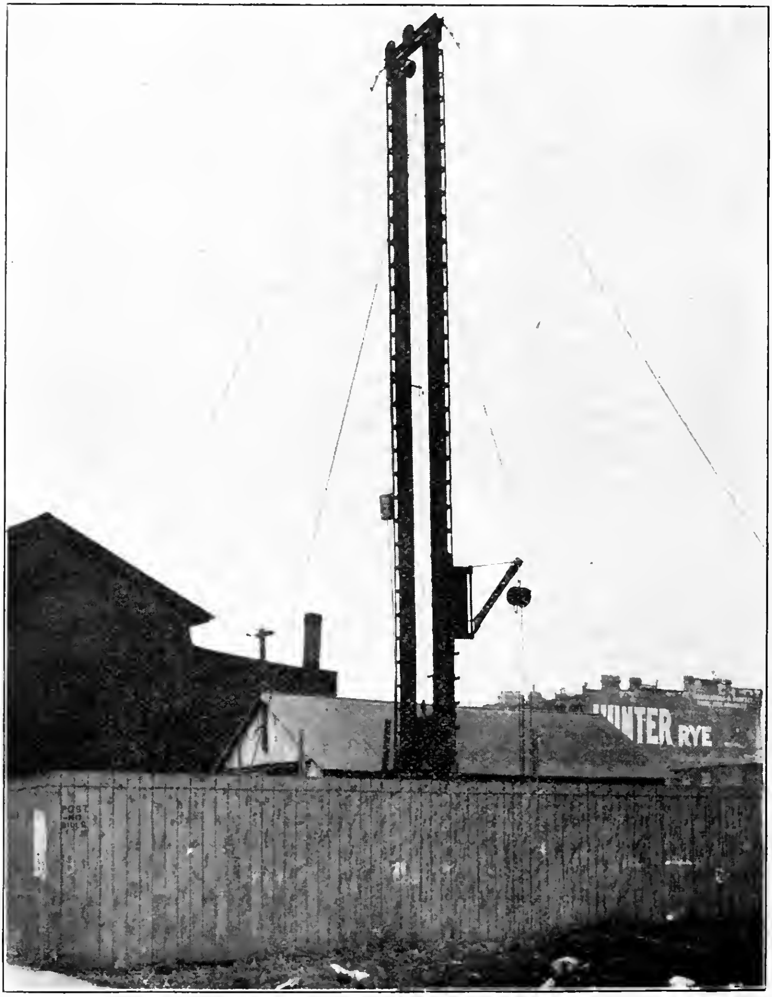



FIG. 4. VIEW OF IMPACT MACHINE.

The energy of the falling hammer, weight 1660 pounds, is

$$5 \times 1660 \text{ or } 8300 \text{ foot pounds.}$$

The efficiency of the dynamometer, then, is

$$\frac{8300 - 1332.5}{8300} = 83.9\%$$

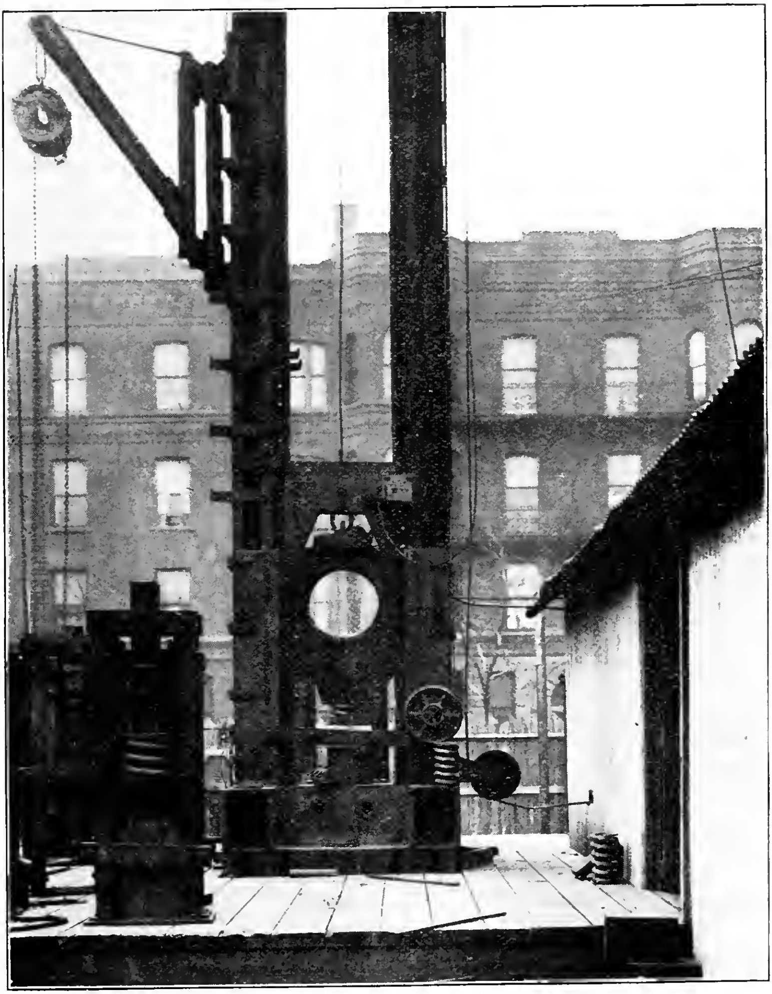


FIG. 5. IMPACT MACHINE. BASE AND ANVIL.

In a like manner, the combined efficiency of the gear and dynamometer is found to be 92.16 per cent.

Let the efficiency of the gear alone be represented by x. Then $1 - x$ is the per cent, and $(1 - x)\ 8300$ is the energy in foot-pounds transmitted to the dynamometer from the gear.

Also $(1 - .839) \times (1 - x) \times 8300$ is the energy transmitted to the foundation by the dynamometer. But from the second card (Fig. 3) we find that this energy is $(1.90 - .9216) \times 8300$.

Hence $(1 - .839) \times (1 - x) \times 8300 = (1 - .9216) \times 8300$

hence $x = (.161 - .0784)/.161 = 51.3$ per cent.

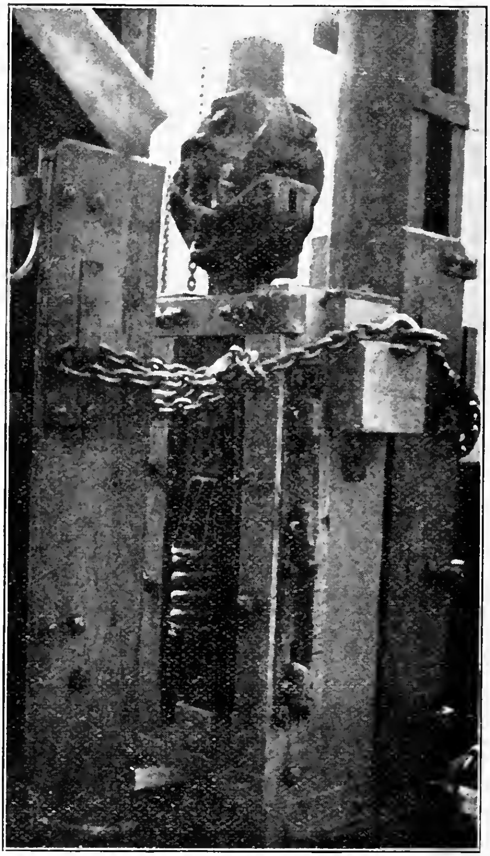


FIG. 6. DRAFT GEAR IN PLACE.

This simply means that 51.3 per cent of the energy imparted to the gear by the falling weight is absorbed in the gear. All gears may be compared on this basis. As shown by the movement of this gear, which had a total compressibility of 4 inches, the force of the blow compressed it 2⅞ divided by 4 or 72 per cent of its maximum compression.

The card shows that the pressure vibrates above and below the ordinary pressure line, that due to the pressure of the water in the dynamometer when at rest, and finally assumes a new pressure line. This latter is due to the increased weight on the receiving plunger after the blow, before the magnet picks up the hammer; while the former is caused by the recoil of the springs.

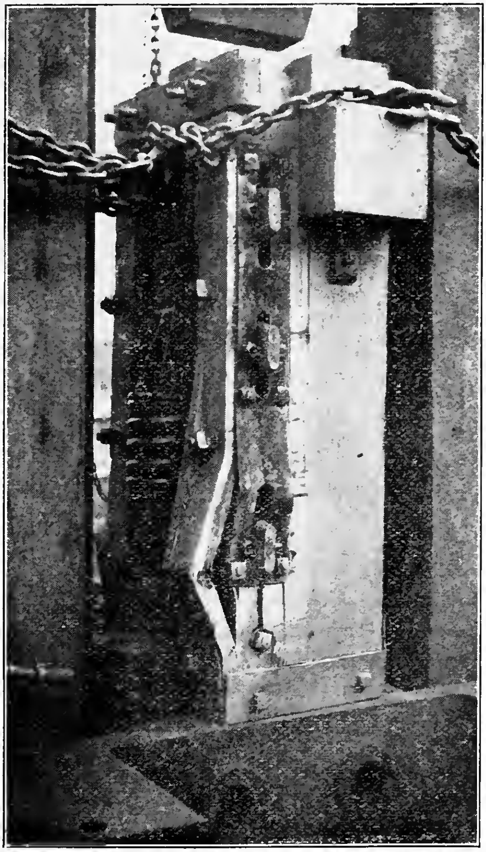


FIG. 7. DRAFT GEAR AFTER DESTRUCTION.

Practically no work has ever been done except perhaps by the Ordnance Department of the Government in testing the effect of impact on various metal shapes and no work at all has been done in testing draft gears on any form of dynamometer, so that the drop test machine and its equipment at Armour Institute of Technology offer a very fruitful field for research work of this kind.

# A NEW METHOD OF SUGAR MANUFACTURE.

BY E. W. McMULLEN.*

The world's sugar to-day is derived almost entirely from the sugar cane or sugar beet. The production last year (from Willett & Gray's report) shows a total of 14,160,00 tons, of which about one half was from beets and one half from cane. Of this, the United States, with Cuba, Porto Rico, Hawaiian and Philippine Islands, included, raised 2,700,000 tons. This country also imports 500,000 tons, thus consuming 3,200,000 tons or nearly one-fourth of the sugar produced.

The sugar beet is a cultivated vegetable which has been raised by scientific means from an original sugar content of about 5 per cent. to as high as 18 per cent. It flourishes best in temperate climates, decreasing in quality with advance southward. For instance, Idaho beets have about 18 per cent. sugar and 85 to 88 per cent. purity, while Ohio beets have 14.5 per cent. sugar and from 82 to 84 per cent. purity. An exception to this rule exists in Colorado where 18 per cent. sugar is obtained but the purity is slightly less than in the Idaho beets. The California beets have a very high sugar content but a low purity.

The sugar cane on the contrary flourishes best in the tropics. It decreases in sugar content and purity as it comes north, and is impossible of growth where frosts are common. Tropical cane has a sugar content of about 18 per cent. and a purity of 85 to 90 per cent.; this decreases to about 12 per cent. sugar content and 778 to 84 per cent purity in Louisiana and similar districts. The cause of this fact is that cane degenerates in cooler climates and also that the crop must be harvested before coming to maturity on account danger from frost. In such countries as Louisiana, new cane is planted every three years because of this degeneration. The new cane is imported generally from the Demerra experiment station which has done much for good cane cultivation.

The season which the sugar beet factories may run is very limited. The beets ripen about Oct. 1st and begin to spoil in storage by Jan. 1st. Thus the outside limit of the sugar beet campaign is 100 days. A slight exception is true in California. It may be seen very readily that this causes a great waste of time, nearly nine months per year, and consequently a loss in interest on investment. Sugar cane is first cut in September in such places as Louisiana, and must be used by the middle of January because of danger from frost This gives a season of from four to four and a half months at best. In the tropics,

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*Class 1909. Chemical Engineering. Armour Institute of Technology.

the cane may be matured further, until November; and it will keep until the following May without noticeable deterioration. It may be cut whenever wanted. This allows a season of about six months, which is the longest sugar season obtainable at the present time.

The preceding paragraphs are a brief statement of the extent of the present sugar business, the raw material from which sugar is made, and the important time element entering into the present manufacture, and will enable the reader to fully understand the changes introduced by the new process I wish to describe, and the conclusions drawn therefrom. The new process in brief consists in drying the sugar bearing plant, either the beet or cane, before extracting the sugar. There are two very self evident advantages to such a process if it be properly carried out: first, the possibility of working a sugar house the entire twelve months of the year on the material dried during the season: second, the saving due to non-deterioration of the raw plant. At the present time this deterioration amounts to about ten per cent. on the average beet campaign; and while not so much on cane, it is still considerable in such places as Louisiana. There are other and much greater advantages which will be brought out in the following.

The most important feature in the process is the machine for drying the beets or cane, the construction and application of which is the invention of my father, Mr. G. W. McMullen. This machine is in a building about 60 ft. long, 20 ft. high and 13 ft. wide built of concrete. The material to be dried enters through a hopper at the top and is spread on the first of a system of endless belts each 50 ft. long and nearly the full width of the building. There are twenty belts in the machine. The material is carried along the top belt, drops to the second, is carried back in the reverse direction, drops to the third, and so on until the circuit of the machine is completed. The speed of the belt is so arranged that the material is dry when it leaves the bottom belt. The heating inside the kiln is done by steam pipes placed under the top side of each belt, which means directly under the load of wet material. The dry preheated air which is admitted at different points throughout the machine takes up moisture from the hot material and is drawn out through air ducts by means of a suction fan. The temperature maintained is from 170 to 180 degrees Fahr., at which temperature no sugar will be inverted in the time required for drying. It is this noninversion of sugar which is the difference between this and other schemes which have been tried.

The accompanying figures will give a good idea of this form of dryer. These are taken from an experimental dryer erected at the plant of the Variety Mfg. Co., Chicago. It is of similar

construction to that described, except that the frame is built of structural steel instead of being built into concrete walls. This structural steel makes more expensive construction but was necessary for the experimental plant as it was not to be located permanently. The machine was simply erected on an open space and enclosed by double walls of matched timber, paper lined. The figures were taken with one side open. Fig. 1 shows the side of the machine which is forty feet long, with the ten horse power induction motor used to move the belts, and also the steam heating pipes and perforated suction ducts for the heated air. The large square pipe is the main air duct

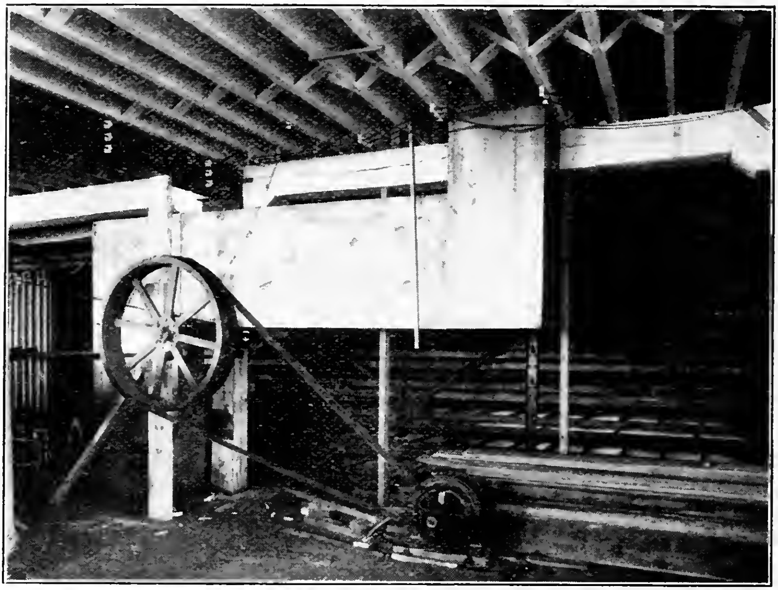

Fig. 1.

which leads to an exhaust fan on the floor above. Fig. 2 shows one end and part of the same side of the machine; it illustrates the gearing of the 9 belts and the projection of a belt to catch the material from the belt above. These gears turn at 6 R. P. M. and a sample belt of similar wire netting, 32 gauge with 12 meshes to the inch, shows no sign of crystallization after some 100,000 turns. The belts are 9 feet wide, 40 feet from center to center of shafts, and 8 inches from top to bottom of each belt. This machine shows a capacity of 18 tons of cane per day which is slightly under one fourth of the capacity of the large machine previously described.

The beets to be dried are sliced into cossettes in the ordinary way; the cane shredded into material resembling wet excelsior. The shredder to do this work is new and was developed and is now used by ex-Governor Warmoth of Louisiana on his plantation. His large shredder has a capacity of 1.500 tons of cane per day. A smaller one was built and used with the experimental machine described. The beet cossettes take from 2.5 to 3 hours to dry and the shredded cane. less than one hour on account of its fine subdivision.

After drying, the material may be made ready for shipment or the sugar extracted from it on the spot. The cane is readily pressed into bales similar to the cotton bale; the beets have to be ground after drying to put them in the form of a course powder which gives the best extraction and most ready expression of water from the sugarless pulp. The dry powder may be shipped in bags or cars. The great peculiarity and advantage of these dried materials is that they carry only a small per cent. of moisture, dried beets from 3 to 4 per cent. and dried cane from .5 to 6 per cent. and will not absorb more from the air. We have had some dried beets in the laboratory at Armour Institute of Technology for over a year which are as dry as when ground. There is absolutely no change or inversion of any of the contents.

The dried beets or cane may be diffused in a manner similar to that now used with raw sugar beets. But with the raw beets, hot water from 180 to 200 degrees F., has to be used; with the dried material, cold water is used. In the experimental diffusion battery set up in the Armour laboratories, the city water supply is directly connected to the battery. In the diffusion of raw beets, 12 cells in series are used and 0.3 per cent. sugar is left in the pulp; with the dried material, 5 cells are used and complete extraction of sugar is obtained from both beet and cane. This loss of .3 per cent. sugar in the present method means a loss of 27 cents per ton of beets or from $12,000 to $15,000 per year in an ordinary beet factory. The present method of extracting sugar from sugar cane is by crushing the juice out under heavy rollers. The refuse is washed with hot water and crushed a second and third time. The sugar loss in the refuse or bagasse is from 2.5 to 5.5 per cent. on an 18 per cent. cane, or from 14 to 30 per cent. of the total sugar. (Newland's Sugar Handbook, 1909.) Thus the average loss of sugar is above 4 tons on 100 tons of cane or $2.00 per ton of cane. When we think of the 60,000,000 tons of cane raised yearly, we must see that about $120,000,000 are being thrown into the rivers or burned up under the boilers. This baggasse is usually burned under the boilers; it is quite wet and has a poor fuel value, about one third that of coal. As

will be seen later, the cane fiber as recovered by the new process is worth above $40 per ton. Thus $120 worth of fiber is burned to get the equivalent of one ton of coal.

There have been many attempts to diffuse raw cane. The only successful one is that of ex-Governor Warmoth of Louisiana whose shredder was previously mentioned. Cane is shredded in the manner described and diffuses with very hot water, up to 200 degrees F. A very lean juice is obtained, ten degrees Brix, in twelve cells and a very low purity, 78 to 80 per cent. The refuse is so wet that it will not burn so it is pumped into the Mississippi River at the rate of $3,000 worth per day. Cane from that locality dried in the manner described gave in four

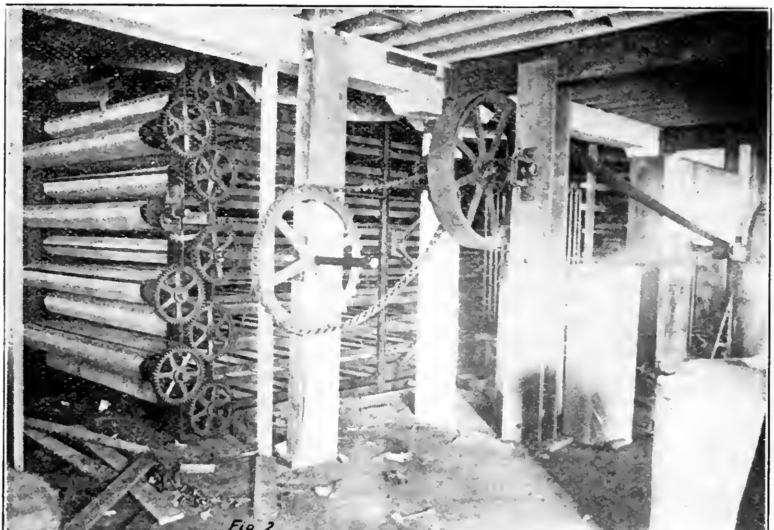


FIG. 2

cells a juice of 20 degrees Brix and 84 per cent purity and complete extraction when carried on to the fifth cell, as there was not enough sample to fill five cells The density of the juice from the squeezing of the cane depends upon the amount of washing, and is from ten to sixteen degrees Brix, the latter percentage being only obtained when a large amount of sugar is left in the bagasse. From the dried cane, juice above twenty degrees Brix is readily obtained. Above twenty-five degrees it is very difficult to purify. The juice from the raw beet diffusion is from twelve to fifteen degrees Brix while from the dried beets it is a high as can be handled, thirty-four degrees has been obtained, and shows a consistant increase of purity of two to three per cent. over the hot water diffusion.

There is of course a good reason for this difference in diffusion. In the raw beets or cane, diffusion is due to the osmotic pressure of the sugar solution contained in the plant cells, since the walls of these cells act as the semi permeable membrane. Some of these cells are cut in the slicing and the juice in these is readily dissolved, but the majority are not cut and so theoretically it would take an indefinite amount of water to get complete extraction from the raw plants. As osmotic pressure increases with the temperature, hot water is used and hence many impurities go into the juice which are not soluble in cold water. In the process of drying the cell walls break down along with the escape of water, and hence the process is no longer diffusion in the true sense but merely solution. This then is the reason that cold water may be used with dried material and that absolutely complete extraction is obtained with so little water.

The residue from the dried beets is a pulp from which 70 per cent. of the water is easily removed by drying because the cells are now broken down. This dried pulp containing 9.5 per cent. protein, may be mixed with the molasses in the proportions in which they are formed. The combination forms a very fine food worth about $25 per ton. The following average analysis of tropical sugar cane is taken from Newland's Handbook of Sugar:

| | |
|---|---|
| Water | 71.04% |
| Saccharine | 18.02 |
| Cellulose | 9.56 |
| Albumenoids and Mineral Ash | 1.38 |

It is readily seen that when the water and sugar are removed with about one per cent. of other impurities, a very pure cellulose is left. In this form with the cells broken down, 75 to 80 per eent. of the water may be removed by squeezing, and the rest evaporated or left in according to freight rates. There is no deterioation of the cellulose since all the sugar has been removed and there is scarcely a noticeable odor after keeping several months in this damp stae. This cellulose forms a very valuable paper stock for which there is unlimited market at the present time The pure fiber is worth over $50 per ton on a rising market, so that the entire residue may be placed at well over $40 per ton in unlimited quantities.

The juices from both dried cane and beet solution may be carbonated, filtered, evaporated, and centrifuged in the ordinary manner; the only difference being a great saving in the evaporation necessary. To install the new process in a sugar house no new machinery is necessary and the old machinery will show a much greater capacity than formerly. Most sugar houses

have beets shipped in from some distance so that if drying is done at the farms as is planned the saving of freight would nearly pay for the drying. Of course this would not hold good for cane plantations where the entire supply is grown near the sugar house.

**Beet Sugar:**

The average beet sugar factory cuts from 500 to 700 tons daily with an average season of from 75 to 85 days Its cost approximates $1,000 for each ton of beets cut daily or for such a factory about $500,000. The deterioration, taxes, insurance, and interest charges amount to at least 12 per cent. annually or on such a factory $72.00 per year. Its season's cut will be about 50,000 tons so that this charge will be $1.44 per ton of beets cut. There is also in every beet factory running the season a deterioration of at least ten per cent. on the beets due to spoiling, frost, etc. This amounts to 55 cents on one ton of average beets costing $5.50. The sugar wasted in pulp is equal to 0.3 per cent or 27 cents on a ton of beets. This makes the total cost outside of the actual refining, $2.26 per ton of beets cut.

By the new method running the plant the entire year,200,000 tons could be treated in the same factory that now treats 50,000 tons, so that the interest charge of $1.44 would become $0.36 per ton. The deterioration and waste of sugar in the pulp would be eliminated. The outlay for the dryers to handle the 200,000 tons in the available season would be about $420,000. Assume interest charges 12 per cent. as before, or $50,000 or 25 cents per ton of beets.

The cost of drying above present handling is about 50 cents per ton of beets, against which there is the saving in evaporation. Assume a 25 degree Brix juice by the new method as against a 12.5 degree juice by the old. The saving in evaporation is equal to 4-7 or 57.1 per cent. Assuming 80 lbs. of water evaporated for 12.5 lbs. of sugar by the old method, this means a saving in evaporation of 46 lbs of water by the new method. Assuming 250 lbs. of sugar per ton of beets, this means 920 lbs. of water at a cost of about 20 cents. This gives a total cost outside of the refining for the new method of

$$35+25+50\times20=91 \text{ cents per ton.}$$

The gain by the new method is therefore equal to $2.26 minus $0.91 equal to $1.35 per ton. The pulp from the dried and ground beets with the molasses added will be ten per cent on the original beet. The cattle food made is worth $25 per ton or $250 per ton of beets. The molasses now brings $9.00 per ton of beets. This leaves $2.05 profit on the pulp against which is the cost of preparation, about 12 cents per ton of beets. Some

new factories now dry their pulp but the process is expensive due to the high water content and cellular structure of the pulp. We will allow \$0.15 per ton on the beets for the present profit in the pulp which is more than is generally obtained. This leaves \$1.778 per ton of beets, add to this the \$1.35 previously obtained and we have \$3.13, the net profit per ton of beets of the new method aginst the old. It takes slightly over 8 tons of beets to make one ton of sugar, so that the net gain will be \$3.13 or \$25.04 per ton of sugar, or 1.25 cents per lb. of sugar.

**Cane sugar:**

The great saving on cane sugar consists in utilizing materials that are now wasted. The extension of season is from six to twelve months, but as the plants cost much less per ton cut than do beet plants, and coal costs more, this saving may be neglected. The present method recovers from 66 to 85 per cent. of the saccharine matte, the new method 100 per cent., or an average saving of 25 per cent. of sugar. On an eighteen per cent. cane, this means 90 lbs. of sugar per ton worth 2¼ cents per pound in Cuba, or \$2.00 per ton of cane. The recovered fiber amounts to 8.5 per cent. or 170 lbs. per ton of cane. At \$40 per ton, it would bring in \$3.40 per ton of cane. At present it is worth \$2.00 per ton as fuel, or 17 cents per ton of cane. This leaves \$3.23 net return from the fiber. The dryers for cane do twice as much per day as do beet dryers and have twice the length of season. Hence the interest charge will be ¼ that for beets or 6¼ cents per ton of cane. Owing to the higher price of coal in the tropics, the cost of drying cane would be nearly as much per ton as beets, say fifty cents per ton. The saving in evaporation would be the same as for beets equal to 20 cents per ton. Summing up, the net saving will be as follows:

$$\$2.00+3.23-.0625-.50+.20=\$4.86 \text{ per ton.}$$

It takes seven tons of cane to make one ton of sugar, so that the saving per ton of sugar is equal to 7x\$4.86 or \$34.02. This is 1.7 cents per lb. or 75 per cent. of its present cost in Cuba.

# REINFORCED CONCRETE DESIGNING.

## A Paper Before the Members of the Armour Civil Engineering Society, Armour Institute of Technology, Chicago, Ill., Nov. 17, 1908.

BY ERNEST McCULLOUGH.*

This paper will deal with some practical things not mentioned in the current treatises on reinforced concrete design. At present there is much of a sameness in the books. They all reprint reports of tests that have been distributed free by the institutions and societies issuing them. They also print extracts from the technical papers of work done in this material and all the books print practically the same descriptions because they are abstracted from the same papers. They all go heavily into the qualities desirable in the aggregate and often they go in much too fine a manner into the mixing and proportioning. for it happens in actual work we have to use what we can get and do the best possible with it. All the books then treat in a more or less complete manner with the mechanics of reinforced concrete construction and they are done.

Now it happens that an item often mentioned in specifications is that of deflection and none of the standard books say one word on the subject. There are a great many engineers and architects turning out plans for reinforced concrete structures and they have a number of different methods of designing, yet the books do not take any notice of the assumptions made by designers; and the student when he goes out into offices to work is at sea regarding many important details. Therefore in this paper it is my intention to confine myself to these little practical points that bother a young man when he leaves school and goes out as a reinforced concrete engineer. Because the student has to learn these things after long experience, it is safe to say that ninety-five per cent of the buildings erected today in reinforced concrete have the benefit of the salesman of reinforcing material in mind rather than any benefit to the owner.

Owners today want reinforced concrete buildings because of their many good qualities, chief of which is the lessening of the cost of insurance. We therefore see many sets of specifications coming from the offices of men who know little or nothing about the work but who try to do the best they can under the circumstances. The obvious thing for an architect to do is to have some manufacturer of reinforcing material prepare his detail drawings, trying in some way to protect the owner by specifying things he believes are right.

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It is common therefore to see rigid specifications for deflection. That is the architect believes them to be rigid, whereas the manner of wording the deflection clause shows the reinforced concrete designer that he has here some one easy with whom to deal.

It happens that a deflection of 1/360 of the span will not crack plastering so that very often we see a clause to the effect that the deflection under test load must not exceed 1/360 of the span. From this amount it ranges to 1/1500 of the span. It is pretty safe to say it is all guess work after all.

Now as it happens this matter of deflection is one not yet settled and one that experimenters have apparently considered as hardly worth notice. When a specification comes in settling the amount of allowable deflection we have to be pretty careful in our designing for we only know in a general way that the deflection of a reinforced concrete beam is about one-third that of a steel beam of equal strength and that a deflection that will crack the plaster on the under part of a beam or slab will undoubtedly be enough to permanently injure it. The elastic limit of the steel will have been long passed and the concrete will be on the verge of failure.

Some architects go even farther however and call for loads that will destroy the slab. Here is a copy of a specification that came into our hands one day lately:

> "Before wood top floors are put on, the reinforced concrete floors must be subjected to a test, in the presence of the Superintendent. This test will be made by the Contractor and will consist of loading any, or all, parts of the floors, as the Superintendent may designate, with a dead load of Three Hundred and Fifty (350) pounds per square foot. When this test is applied, should any part of the reinforcing system fail, crack, sag, or unduly deflect, the entire system will be rejected and the Contractor required to take out the entire system and rebuild until a satisfactory test is had."

The foregoing specifications were for a school house. A dead load of forty pounds, a proper test load would have been twice the live load plus once the dead load, or two hundred pounds per square foot. Such a test load should have stressed the steel to not more than ninety per cent of the elastic limit and the concrete to not more than three-fourths its ultimate strength.

The test load called for should have been sufficient, under many systems of designing, to have brought the floors to the verge of failure and yet the deflection would not have been sufficient to have cracked the plaster. Notice also how indefinite are the provisions. If the floor deflects unduly then the contractor must take it out. Suppose the architect when he drew those specifications had in mind a deflection of about 1/400 the span. Suppose that some reinforcing company had prepared plans for the contractor for nothing and had figured his sections so light that a deflection of about this amount would be secured. Suppose that in the meantime before the test is made that the architect had been informed by a disappointed bidder as to what he should expect and then imagine the result when the contractor has to take out the floors and rebuild them because of excessive deflection under test load.

Being an engineer for a reinforcing company and having many designs coming into the office it has been a matter of interest to me to draw out some of the men whose plans were sent to our office. Whenever a set of specifications came in with a deflection clause we wrote to the architect asking for the formula by which he computed the allowable deflection. We told him that this was one of the unsettled points in reinforced concrete design and therefore wanted to know his method of figuring the matter in order that we could design to meet his requirements. The majority of the men never replied to our letters. A few however wrote and told us that they knew nothing about it and had supposed the deflection for a steel beam should be about right.

When you get your reference books into your hands again just look this matter up. We plotted the results of all published tests and tried to obtain a good formula but the results were too discordant. The subject of deflections seemingly did not interest American experimenters. European experimenters did pay attention to this matter and it is easier to work after them. Professor Maurer of Wisconsin State University permitted me to copy a deflection formula he has lately developed as a result of his study of European beam tests but I do not feel at liberty to give it here without his permission. It agrees very closely with loads up to one third the ultimate and should be extremely useful when he has finished working on it.

The only other guide we have is a formula proposed by Mr. Eli White in The Engineering Record for Nov. 9, 1907, so you see the subject of deflections is quite a recent one.

Mr. White first ascertains the position of the neutral axis and considers it as midway between the actual reinforcement in the bottom of the beam and an equal amount of imaginary reinforcement above, and wholly outside the beam. The full discussion is to be found in the paper mentioned. After all

the transformations and substitutions rendered necessary to get it into agreement with ordinary deflection formulas, we finally obtain:

$$\text{Deflection in inches} = \frac{f_s l^2}{M\,(d-k) \times 1{,}000{,}000}$$

in which f = fiber stress in the steel under assumed loading.
l = span in inches.
d = effective depth from top of beam to center of steel.
k = depth of neutral axis from top of beam.
M = multiplier = 288 for uniformly distributed load on beam freely supported at both ends.
= 384 for partially constrained beam.
= 480 for tied or constrained beam.

This method is only closely approximate and gives a deflection somewhat in excess of the actual deflection under load. When the specifications call for a test load and a certain deflection under the load it would be well to find the steel stress under the test load and then use this formula in order to know in advance what to expect.

An architect has a perfect right to call for a deflection not exceeding 1/1000 of the span under a test load consisting of twice the live load plus once the dead load, thus securing as an actual test load twice the estimated load the slab or beam will ever be called upon to carry.

Testing my designs by the above formula we found in three instances that the deflection limit set, called for much more steel than was really required and on taking the matter up with the men for whom the plans were wanted they readily agreed to leave out the test load and omit the deflection clause provided we gave them the detailed calculations for the work and took our oath that they were actually the calculations for the structure and referred them to books where the formulas could be found.

Yet with a proper check upon design, such as is given by an intelligent requirement for deflection, it may be possible to give a much better shape to a beam than would be given under the ordinary rush conditions existing in a competitive designing office.

Another thing found in specifications is a factor of safety clause. It is easy to write that the work as designed shall have a factor of safety of four and this requirement is common. Nine times out of ten we find that the man who prepared the specifications meant that the floor should be able to carry four times the specified live load.

To an engineer a factor of safety implies the quotient obtained by dividing the ultimate strength of the material by the fiber stress allowed. That is to say, if the steel has an ultimate strength of 64,000 lbs. per sq. in. in tension we have a factor of safety of four when we stress it only 16,000 lbs. per sq. in. The man who prepares the specifications will tell you he means just that also, but if you put up to him a floor weighing 150 lbs. per sq. ft. to carry a live load of 100 lbs. he will begin to hedge. Assuming a dead load of 150 lbs. and a superimposed safe load (live load) of 100 lbs., the total is 250 lbs. per sq. ft. and four times this is 1,000 lbs. The man who prepares the specifications will be perfectly satisfied if the floor can carry an ultimate (breaking) load of once the dead load plus four times the live load, or a total of 550 lbs. per sq. ft. Much of the designing done today does not take into consideration the disproportion of dead to live load in reinforced concrete structures and happenings such as that just mentioned are common.

I have stated that ninety-five per cent of the buildings designed in reinforced concrete today have been designed with the benefit of the manufacturer of reinforcing material in mind rather than with the benefit to the owner as a paramount consideration. It may not just now be known, but not five per cent of the reinforced concrete buildings are designed in the offices of the men whose names appear upon the plans and drawings. One reason is that the average architect does not have calls enough for this class of structure and therefore does not attempt to design the reinforced concrete work. He simply makes the plans for the buildings and prepares the specifications. Then either has some reinforcing company prepare the plans for nothing or draws the specifications so that all systems have a show and the contractors have the plans prepared by the companies from whom the reinforcement is purchased.

Another reason is that very many men while presumably competent do not care to waste their time, for they feel that some salesman representing some special system of reinforcement will try to make the owner switch over from the plans prepared by the architect. A third reason is that the wise architect considers himself in pocket if he leaves the designing to the numerous companies so ready to do the work at no cost to him or the owner, in the hope of selling their material. Therefore it is customary to have a clause in the specifications to the effect that:

> "Contractors bidding on the reinforcement will be permitted to bid on any system desired and must submit with their bids full drawings and computations in order that the architect may check the work, etc., etc."

Then follows a few little things to guide the designers. It happens very often that the specifications do guide some of the designers so they know the man with whom they have to deal can be given anything they feel like giving him. It is seldom we get in a set of specifications that indicates much intelligence on the part of the writer so far as they relate to reinforced concrete. Occasionally some specifications come in that show the man who prepared them was thoroughly up to date but such a man generally has his plans fully drawn and no good changes can be made. It is seldom that any special system of reinforcement gets in on such a man's work for his own design is usually as economical as any that any contractor can obtain.

Generally however the architect simply prepares the plans of the building and everything connected with it except the reinforced concrete work and permits contractors to submit plans of their own for that. These plans are obtained by the contractors sending blue prints to reinforcing companies and asking them to submit bids for the reinforcement together with blue prints showing how they propose to do it. The time given the reinforcing company in which to do the designing is usually from one to three days, the latter being quite a liberal time and the engineers who have the designing to do feel quite grateful to a contractor who will permit them to work three days on the designs. By days we mean days of about eighteen to twenty hours each. We have worked three days on plans that should properly have taken three weeks time. It is hardly to be expected that niceties of detail can be indulged very much under the circumstances; but every engineer remembers that each of his competitors is also at work, so he must design as economically as possible if his employer is to get the work. If he forgets to multiply by two or three his firm of course stands a better chance to secure the job but it means many weary achy hours of skinning afterwards so there will be no loss, and so that the architect will not discover any great discrepancy between the preliminary plans and the final drawings.

It is a miserable system but there is no hope of getting away from it. The only thing we can do is to teach men how to write proper specifications so the owner will be protected and so honest manufacturers will be protected against men who will skin to save a dollar; no even to save a dime. On this account every firm has tables and diagrams to shorten labor and make the designing as nearly mechanical as possible. After all it is merely clerical work when one comes to think of it.

Before I finish I will give you some specifications so that the man using them should come somewhere near to obtaining uniformity of design in plans he sends out for competitive bidding.

I propose to take up a typical building floor and to go through it in several ways to show how different designers will tackle the work and thus show how an architect can easily be puzzled to select a system and at the same time avoid being charged by the owner as having been bought up, in case he selects a system that is not the lowest in cost. It nearly all hinges on the prooprtion of dead to live load and on the meaning of the term "factor of safety."

The floor selected is to be one hundred feet long and fifty feet wide. The owner is prejudiced against tile and will not permit its use, even in combination with reinforced concerte, thus not allowing any lessening of dead load, such as is effected by tile when set in floors of ribbed design. The owner has been talked into the use of long spans but he does not realize how much this means in the item of increased weight, which means larger columns and heavier foundations as well as larger beams and girders. This also means that the steel and concrete are unduly stressed carrying their own weight.

The specifications fix the live load (safe superimposed load) at one hundred pounds per square foot. It is also stated that the factor of safety shall be four. Nothing is said about the fiber stress in the materials. The blue prints of the building together with the specifications go into the hands of the contractors and six companies get an opportunity to bid on the reinforcing material. As the architect has spaced his columns 16 ft. 4 in. on centers and will permit only two girders lengthwise of the building and will not permit any beams, it is necessary to make slabs from side to side.

The conditions are such that we should really use for bending moment $wl^2/10$ for the two outside spans and perhaps $wl^2/10$ for the inside span. However all the designers know that each of the others is going to figure as small a bending moment as possible so all will use $wl^2/12$. We are here considering that the men doing the work are not very bad men or they might use $wl^2/16$, as I have known a great many to do. So in this competition we will consider them all alike in their assumption of bending moment conditions and we will take it for granted they will all use a ratio of deformation between steel and concrete of 15. As a matter of fact they will not all do it but we must get somewhere on a common ground.

The accompanying table shows all the conditions in detail so we will consider them one by one.

One designer who wants to be honest assumes for his weight the sum of the dead and live loads, and after several trials gets a slab seven inches thick. He assumes a fiber stress of 16,000 lbs. in the steel and of 700 lbs. in the concerte. He uses the straight line assumption, which is best for buildings and the safest generally. The table shows the stresses he

gets under only the dead load as well as under the dead and live load. . The cost of this floor (exclusive of form work) is $0.227 per square foot. The weight of a square panel is 23,400 lbs. which is to be carried by each column.

| Case. | Thickness of slab. | Wt. Slab lbs. sq. ft. | Depth to center of steel. | Depth to neutral axis, % | Moment Arm. % | Steel ratio. | Steel area sq. ins. | Steel stress. Dead load only |
|---|---|---|---|---|---|---|---|---|
| 1 | 7 " | 87.5 | 5.88 | .398 | .867 | .0087 | .512 | 7500 |
| 2 | 5½" | 67.8 | 4.33 | .414 | .862 | .0097 | .500 | 8200 |
| 3 | 5½" | 67.8 | 4.5 | .427 | .858 | .0107 | .578 | 6850 |
| 4 | 6 " | 75.0 | 5.0 | .599 | .775 | .02 | 1.20 | 3560 |
| 5 | 4½" | 56.3 | 3.33 | .584 | .781 | .0183 | .731 | 6590 |

| Case | Steel stress. Dead and Live load. | Concrete stress | | Cost per square foot. (exclusive of forms) | | | Weight of slab in square panel |
|---|---|---|---|---|---|---|---|
| | | Dead load only | Dead and live load | Steel | Concrete | Total | |
| 1 | 16000 | 328 | 700 | $0.052 | $0.175 | $0.227 | 23400 |
| 2 | 20000 | 384 | 940 | 0.049 | 0.138 | 0.187 | 18350 |
| 3 | 17700 | 344 | 890 | 0.059 | 0.138 | 0.197 | 18350 |
| 4 | 8350 | 122 | 278 | 0.122 | 0.15 | 0.272 | 20000 |
| 5 | 19050 | 403 | 1195 | 0.074 | 0.116 | 0.19 | 15000 |

On the straight line theory it is absolutely wrong to figure ultimate values in steel and in concrete, yet it is often done. The second man multiplies his live load by four, adds the dead load and uses the ultimate strength of the steel, 64,000 lbs. per sq. in., and the ultimate (assumed) strength of the concrete, 3,000 lbs. He gets a fiber stress of 20,000 lbs. in his steel under the dead and live load, and a fiber stress in his concrete of 940 lbs. The cost of this floor without form work, will be $0.187 per sq. ft. and the weight carried to each column will be 18,350 lbs.

The third man does not believe in figuring ultimate values on the straight line basis yet he does not like to figure in all his dead load. He therefore assumes a fiber stress of 16,000 lbs. in his steel and 800 in his concrete, takes half the dead load, plus the live load and gets an actual stress in his steel of 17,700 lbs. and in his concrete of 890 lbs. under the combined dead and live load, instead of the fiber stresses assumed.

The fourth man is a college boy just out of school and very anxious to do things up right. He assumes four times the sum of the dead and live load and uses the parabolic theory

of stress. His assumption for the steel is based on the steel being stressed to two-thirds the elastic limit and the concrete to two-thirds its ultimate strength. The elasic limit of his steel is 60,000 lbs. so he uses 40,000 lbs. The ultimate strength of the concrete he assumes at 3,000 lbs., so he uses 2,000 lbs. An examination of the tabulated results will show how much chance he has to win out in a contest for competitive designs.

The fifth man is wiser and designs also by the parabolic method but assumes the ultimate strength of the steel at 64,000 lbs. and the ultimate strength of the concrete at 3,000 lbs. He assumes once the dead load plus four times the live load. The table shows the results obtained.

It may be stated here that the parabolic theory calls for more steel than the straight line theory so that the steel and concrete theoretically should fail together. The straight line theory gives a more rigid construction and therefore better for moving loads while the excess of concrete permits some deflection to show long before the point of ultimate failure is reached.

There might have been some other common assumptions mentioned. Sometimes the specifications call for a test load. If this load is ridiculously low, as it often is, the designer will ignore the factor of safety clause. You will find him designing so that the test load will stress the steel to about ninety-five per cent of the elastic limit and the concrete to about three-fourths its assumed ultimate strength. Sometimes the designer will ignore the elastic limit and design so that the test load will stress the steel to three-fourths of its ultimate strength and the concrete to about ninety-five per cent of its assumed ultimate strength. Instances have been known of some panels being specially constructed for the test load and in some way during the progress of the work the superintendent will have his attention directed to that panel in a manner that will make him select it as the one to be tested.

While the foregoing assumptions give much food for thought remember that we have not gone far from a common stress in the steel whereas designers are very free in their stress assumptions. I have had to check over plans where the steel stress was over 30,000 lbs., although the specifications called for half of that; and in which the concrete stress was over 2000 lbs., although the specifications set 800 lbs. as a limit.

I have had to check over plans where the architect specified fibre stresses of 16000 lbs. in the steel, and 650 lbs. in the concrete with a ratio of deformation of 15, where the man who secured the contract took the dead load plus four times the live load, divided them by four and then used the stresses called for. The live load in one case I remember was 100 lbs.

per sq. ft. but under the assumptions made by the designer the live load was only a little over thirty pounds per sq. ft. when these stresses were reached, for the dead load was high.

The only way to get honest competitive designing is for the architect to state exactly what he wants and see that he get it. To get away from the dishonest and ridiculous habit of assuming a slab to weigh only half it actually weighs there should be a clause to the effect that the floor and beams supporting it shall weigh not to exceed two-thirds the live load and preference will be given to the plan providing a floor that weighs not to exceed one-half the live load. Then when the designer gets to work he will add fifty per cent to the live load and equate for span.

Let $W$ = total load on the span, per foot wide.

$l$ = span.

$M$ = bending moment = resisting moment = $Rbd^2$

then

$l = \sqrt{8M \div W}$ for freely supported beams or slabs.

$l = \sqrt{10M \div W}$ for partially constrained slabs.

$l = \sqrt{12M \div W}$ for constrained slabs.

When the owner understands that the long clear spans he likes so well cost money and that they make a building not so rigid as one having short span floors and roofs and that the extra weight added means increased expense for columns, walls, and footings, he can be led away from the present craze for long spans and no beams or girders. If he does not like the appearance of the beam work he can conceal it by putting in suspended ceilings thus giving him a building easier to warm and allowing him better facilities for running piping and wires.

A curious thing in connection with this long span work in ordinary buildings is the resonance observed. In manufacturing establishments and warehouses this has not been noticed much but when the idea has been carried out in ordinary buildings it has been annoying. In some cases the defect has been cured by hanging a false ceiling underneath the obnoxious solid floor and in some cases false beams have been put in hallways.

The examples given are of a very simple case. The matter might have been quite different in appearance if we had selected a live load of more than one hundred pounds or of less than one hundred pounds. There would have been quite a difference also if the spans selected had been different. The bending moment varies with the square of the span and not directly as the span.

The formulas by which the calculations were made are to be found in Turneaure & Maurer's "Principles of Reinforced Concrete Construction." In all cases the steel and concrete stresses tabulated have been figured by straight line methods. Case 4 involving the elastic limit and a percentage of the ultimate strength of the concrete was figured by the parabolic method to obtain d, j, and k and the per cent of steel. Case 5 where the ultimate strength of both steel and concrete entered into the matter was figured by Talbot's flexure formulas to obtain j, k, d and the per cent of steel. The reason for giving the steel and concrete stresses in the table according to straight line theory was that only working stresses were considered and up to about one-third the ultimate strength of the concrete the difference between the straight line and parabolic theory is small.

It is not so very long ago that nearly all practical superintendents of construction stopped all work directly over the beams where no bending moment exists and where there is no shear.

This is no longer done for it happened the work stopped just where there is the biggest tangle of steel and good joints were hard to obtain. Experiments were made and it was found that it is immaterial where the work is stopped as long as perfect joints are made. Some men stop in the center where there is no shear but there the bending moment is a maximum. It is no doubt best to stop somewhere on the beam or slab where neither shear nor moment are a maximum or a minimum but about where the matter will be equalized.

The slab on top of a beam might readily be used as a part of the beam thus giving us what is called a "T" beam section. Owing however to the joint trouble many engineers objected seriously to T beams. Now however, that we can make joints anywhere it is best to use T beams in all cases, provided they are poured at the same time as the slab.

The first thing to select in a T beam is the depth as this is often a big factor in head room, etc. Having selected the depth we can figure out the width. If the slab is not less than one-fifth the total depth of the beam assumed, we can make a T section of it by having the narrow stem just wide enough to contain the steel. The amount of steel is the percentage obtained by the assumed depth mutiplied by the width found. Thus while the steel percentage might be about one per cent still compared with the size of beam actually obtained it might be three or four per cent.

The width should not exceed one-third the span of the beam and should not exceed eight times the thickness of the slab plus the thickness of the stem enclosing the steel.

Thus we see that ordinary beam formulas may be used for designing T beams. Turneaure & Maurer give an excellent treatment of T beams. The tests of Professor Talbot showed that practically no limit can be set for width except that the wider the beam the greater the deflection and of course the question of shear is very important where the slab and stem join.

I recommend the following specification as one to recommend to architects when sending out plans for competitive designing:

"Designers for the reinforced concrete portion of this building shall be held strictly to the following specifications:

The ratio of deformation between steel and concrete shall be 15. The steel fiber stress shall in no case exceed one-third the elastic limit of the steel and a maximum fiber stress shall be 20,000 lbs. per sq. inch, even if this limit is less than one-third the elastic limit.

Concrete in beams and slabs shall be stressed in the most remote fiber from the neutral axis not to exceed the following: The best broken stone or washed gravel concrete mixed with one part Portland cement, two parts clean coarse sand, four parts clean broken stone or washed gravel, not to exceed 750 lbs. per sq. inch. Such concrete tested in 12-inch cubes at the end of 28 days must show a strength of not less than 2500 lbs. per sq. inch. Concrete made of ready mixed bank gravel or of a 1—3—5 broken stone or gravel, and testing not less than 2000 lbs. in 12-inch cubes, at the end of 28 days can be used with a fiber stress of not to exceed 600 lbs. per sq. inch. Cinder concrete made of a one to seven mixture of clean washed screened cinders can be designed with a fiber stress not exceeding 250 lbs., with a ratio of deformation between the steel and concrete of 30. Concrete in columns reinforced with longitudinal rods or bars shall be stressed not to exceed 500 lbs. per sq. inch. Columns reinforced with wire or fabric having the same hooping effect as wire may be designed so the concrete may be stressed in compression not to exceed 1000 lbs. per sq. inch. No column reinforced only with longitudinal rods or bars can contain more than three per cent of reinforcement. There shall not be more than five per cent of longitudinal reinforcement in wound or hooped columns and the wrapping or hooping shall never be less in amount than the longitudinal reinforcement Columns reinforced with longitudinal bars or rods must have the same tied together at intervals not greater than their distance apart. with wire not smaller than a ten gauge. No deformed or twisted steel can be used in columns. No columns can be made of cinder con-

crete. No broken brick or burnt clay will be permitted in reinforced concrete work, unless it is used under the specifications for cinder concrete.

For one span slabs shall have a bending moment figured as $wl^2/8$. For two and three spans $wl^2/10$ and for more than three spans $wl^2/12$. Beams and girders shall never be figured other than as freely supported with $M = wl^2/8$. Panels perfectly square may be considered as having $M = wl^2/20$ but for panels having one side longer than the other and where the proportion of width to length is less than 1.5 may be calculated as follows: Let r = proportion of load carried by the sides.

L = length of panel.
B = breadth of panel.

then $$r = \frac{L^4}{L^4 + B^4}$$

Having found the proportion of load to go each way use $wl^2/12$ to obtain bending moment. In all cases where the moment is figured for other than freely supported spans there must be adequate reinforcement provided for reverse bending moments at supports. All beams and girders must be reinforced over suports for negative bending moments. Proper reinforcement for internal and web stresses must be provided in all cases where such stresses may exist.

Safe superimposed loads shall be as per the schedule hereto attached. All the live load and dead load on the roof must be carried to the columns. For the first floor below the roof the dead load must all go to the columns but the live load may be reduced five per cent. The live load on each succeeding lower story may be reduced an additional five per cent until a floor shall be reached where the proportion of live load carried to the columns is fifty per cent after which only fifty per cent of the live load on the floors below shall be considered as going to the columns.

Beams shall carry the full dead and live load but girders may be designed to carry all the dead load plus eighty-five per cent of the live load except in storage warehouses.

Thirty days after the forms are removed the superintendent may have the floors, or any portion of them, tested with a load that shall be equal to twice the live load plus the dead load and after said load has been in place twenty-four hours the deflection shall not exceed 1/900 of the span."

If we could prevail upon all architects over the country to put these requirements into the specifications they send out, the effect upon reinforced concrete design would be beneficial.